Roadside infrastructure for safer European roads: D08 European best practice for roadside design: guidelines for maintenance and operations of roadside infrastructure.

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FOREWORD

Maintenance and operations guidelines are an essential element of a road management concept, since the state of the art and the operational status of safety equipment and personnel are the key determinants for the achievable level of Infrastructure Road Safety (IRS). The main components of IRS for the roadside and median areas include the recovery and safety zones, road restraint systems, passive safety equipped support structures, road marking, and traffic signs.

The RISER project is a European project with the objective to provide tools to be applied on a European level as part of the national guidelines and regulations of the EU-member states. For some member states, national maintenance and operation management plans or elements of a plan exist already. However, this is not the case for all member states and it is crucial that all future national road management and safety related activities converge towards uniform European procedures and policies. Not only will this facilitate improved dialogues between the national authorities, it will also ensure that all EU citizens are guaranteed a minimum level of safety on any European road on which they travel.

The following information is presented as a template for future users. There are national and regional issues that arise when it comes to the implementation of European norms or guidelines into the member states. This document should be considered as a starting point for national policies that must be adapted to the local geographical, economic, and demographic conditions. Through the use of a common starting point, commonly accepted best practice procedures will be spread throughout the EU member states and facilitate improved road maintenance, operations, and – most importantly – safety levels throughout the EU.

In view of the current EU focus on road safety it is important to recognize the 3-pillar-concept for road safety being:

- Infrastructure design
- Vehicle design
- Driver (Education)

It is evident that the following information addresses the infrastructure aspect for road safety. It should be recognized that the RISER project has included driver and vehicle aspects to not lose sight of the integrated approach that is required to reduce traffic casualties. This results in the need for a management plan for maintenance and operations aiming for both the basic organisation of maintenance and operations activities as well as its optimization by continual adaptation, up-grading, and logistical improvements.

This document should be used in conjunction with RISER Deliverable 06: ***European best practice for roadside design: Guidelines for roadside infrastructure on new and existing roads.***

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INTRODUCTION

Maintenance and operations of road safety equipment and infrastructure ensure that all safety related elements of the road system are operating as they were designed, tested, and approved. Maintenance of road equipment should not only be considered as the repair of broken or damaged equipment, but also as a potential monitoring system for the road network. This overlooked aspect of maintenance and operations is a central theme for the following sections.

What are the main purposes for developing a maintenance and operations management programme?

There are many reasons to develop or improve the management concept for maintenance and operations of our road network, especially when we are aiming for EU-harmonized guidelines analogous to the performance-related EU-harmonized standards for road restraint systems, road marking etc. Optimization is our overall goal and maintenance logistics plays an important role. Efficient maintenance and operation concepts are a successful combination of cost-effectiveness, logistical organisation, and professional skill.

Maintenance and operations provide an important source of information for the road operator. It is crucial that an inventory of road infrastructure exists and the frequency of repairs, operational functions, and need for replacements can be identified. Without a maintenance programme, these critical issues cannot be addressed.

As essentials of a maintenance and operation management plan we have identified five areas of interest.

- Routine Inspection
- Data Collection
- Data Analysis
- Repair Plan
- Training

These topics cannot be considered separately, but as a total maintenance and operations programme. Information from one area is needed in several other areas. As an example, one can consider the application of road restraint systems. First, inspectors and repair crews must be trained for each type of system applied in their jurisdiction. Secondly, data collection and data analysis allows the inspectors to identify sections where problems are more frequent and observe if the equipment selected is performing appropriately. Thirdly, data collection provides the necessary information for the repair crews to identify the consumption of materials. Thus, the application of a complete maintenance and operations programme ensures that a road operator has the proper equipment in place, an adequate supply of components, and that the road is inspected by qualified individuals, and repaired properly and efficiently by trained staff.

These sectors of the maintenance and operation management plan will be further detailed in the following chapters. The data collection requirements are discussed throughout the document.

CHAPTER 1: ROUTINE INSPECTION

Routine inspections are designed to identify hazards and other defects that affect the traffic safety and therefore require maintenance actions. These activities are required to keep the road system in good order. These inspections do not deal directly with long-term replacement or renewal of the various parts of the highway, although it is recognized that the routine inspection system can play an important role in identifying features that may require eventual replacement or renewal. The focus in this report is on safety barriers but more roadside infrastructure and features should be included in the inspections e.g. road lighting, noise barriers, road signs, etc. All inspection procedures for road safety equipment should be developed in conjunction with manufacturers and suppliers to ensure the technical details are properly addressed.

1.1 Types of Inspection

Three types of routine inspections can be identified for road safety infrastructure. Some inspections will occur regularly according to a schedule reflecting the lifecycle of the infrastructure, whereas some inspections arise due to unplanned events like accidents or severe weather conditions. Thus, the reason for the inspection will be reflected by the purpose for the inspection.

- **Safety inspections** - are designed to identify defects likely to create a danger to the public and therefore require immediate or urgent attention. Such inspections are typically undertaken from a slow moving, double manned vehicle, with the occasional need to proceed on foot.
- **Detailed inspections** - are designed primarily to establish programmes of routine maintenance tasks not requiring urgent execution and are typically undertaken on foot at less frequent intervals than safety inspections.
- **Safety patrols** - are a supplement to safety inspections on the higher priority motorways and trunk roads, in order to provide a more frequent surveillance of the road network to identify serious defects. Safety patrols are typically required to be undertaken in a single manned vehicle, and at speeds as slow as the general traffic conditions allow.

Additional **safety inspections** may be required in response to reports or complaints from the police (e.g. when safety equipment is involved in an accident), the general public, or in response to extreme adverse weather conditions.

The typical issue for the safety patrols is the damage arising from unreported accidents. European research [1] indicates a significant under-reporting of single vehicle collisions in the police reported dataset.

Defects and damage identified during any inspections have to be sorted into different damage levels according to how hazardous they are for the road users:

- **Level A** - requiring prompt attention, as the defect presents an immediate or imminent hazard to road users. Level A defects are required to be corrected or made safe at the time of the inspection, if possible. When this is not possible, temporary or permanent repairs must be completed within (typically) 1-3 hours of detection and, where temporary repairs are adopted, permanent repairs must be undertaken within a set number of days.

- **Level B** - defects which if not treated will get worse and cause major maintenance works at a later date with higher costs as a result. These, just like level A, also need temporary or permanent repair within 24 hours of detection.
- **Level C** -. defects that require eventual repairs. These can be divided further with various levels of repair response times. Their response time can be adjusted to fit into a routine maintenance programme. These defects do not pose an immediate threat to traffic but they may introduce a reduced level of safety.
- **Level D** – defects that require no repair action but should be recorded for further monitoring.

The damage level is closely related to the repair response time which is discussed further in chapter 3. Maintenance of road restraint systems is generally confined to the repair of damaged sections and ensuring correct assembly and operation. The repair of damaged sections of safety fence or barrier will usually be instigated by safety inspections or accident reports from other sources and require prompt attention, as they are likely to pose an increased risk to road users.

1.2 Frequency of Inspections

The frequency of detailed inspections varies according to the inventory items being inspected e.g. motorway safety fences and barriers can be subject to detailed inspection every two years. Other structures in need of detailed inspections with varying time intervals are bridges, tunnels, walls, screens, slopes, drainage systems etc. Many maintenance tasks may be considered minor but failure to undertake them may lead to deterioration of the structure and the need for more serious repairs in the future, like cracks in concrete structures.

The interval between routine safety inspections and safety patrols depends on the type of road. Motorways and main roads are inspected on a daily basis while smaller roads are inspected on a weekly or monthly basis. A classification system of inspection rates is a good way to structure the inspection work. Such a system is usually based on type of road and annual average daily traffic (AADT).

A model by the Federal Highway Administration (FHWA) in the USA considers the time between discovery of defective guardrail and its repair and has been validated in a study [2]. The model says that the time between discovery and repair has to be shorter than the expected time between collisions. If the time between collisions is Poisson distributed with 2 collisions per year, then measures must be undertaken within 9,4 days if you want to be 95% certain that no collisions occur before the measure is undertaken. The guardrail should be inspected with the same interval. The model was verified in a field study and it was found to be acceptable. The only problem was that the model overestimates the risk of a collision where the guardrail already has been hit [3].

A summary of common European practice is presented in Table 1.1. More information about inspection and maintenance practice can be found in RISER Deliverable 7 [4].

Table 1.1. Summary of inspection interval for some European countries.

Country	Summary of inspection interval practice
Finland	Main roads = Every day Other roads = 1-2 times a week
France	Patrols inspect with various frequencies 6 levels of roads: – Around big cities (30-40km) = Several patrols a day – Around big towns (30-40km) = Several patrols a day – Rural motorways (50-70km) = Several patrols a day – Main rural roads linking two big cities (40-50km) = 1-2 times a day or during foreseeable high levels of traffic – Main roads affected by seasonal disruptions (40-50km) = Several patrols a day or during foreseeable high levels of traffic – Other roads (no km) = Patrols not in systematic frequency
Germany	Safety inspection intervals for different road categories: – Motorways: Major lanes every work day Minor lanes 3 times a week – Federal highways 3 times a week – State highways 2 times a week – County roads 1 time a week
The Netherlands	Inspections = Every day If damages or irregularities are found extra inspections will be carried out. A major technical inspection is done every 2-3 months.
Spain	At least 1 time a week – on roads assigned to a maintenance operator. When irregularities appear or an accident has occurred action will be taken according to expert judgement and repaired as soon as possible.
Sweden	Safety inspection intervals for different road categories: – Category 1 1 day – Category 2 2 days – Category 3 7 days – Category 4 14 days – Category 5 21 days Safety barrier: Wire barriers; check the wire tension every 3 years.
United Kingdom	Safety inspections = Weekly/monthly Detailed inspections = Every 5 years (every 2 years if over 10/15 years old) Fences every 5 years Tensioning bolts every 2 years Highway structures: General inspection every 2 years Principal inspection every 6 years

Under special conditions the head of the maintenance depot can determine shorter or longer intervals between inspections:

- **Shorter inspection intervals** - can be necessary on roads with bad road conditions, high traffic volumes, construction sites, threatening hazards, and other extraordinary incidents.
- **Longer inspection intervals** - can be sufficient on roads with low traffic volumes or low incident and accident frequency.

1.3 Reports

The police attending an accident involving road infrastructure damage will contact the road owner. The road owner then dispatches individuals to inspect the damage and assess the repair need. It is a good idea if the public can report damaged road infrastructure to the road owner too, because not all accidents are reported to the police [1].

1.4 Method

The road safety inspector should be knowledgeable in how to install and repair road infrastructure and be familiar with the principles of roadside safety. A good way to ensure this is to create a training programme certificate for road safety inspectors. Typical training issues for the inspector include:

- Proper installation of road restraint systems (familiar with drawings and dimensions of components)
- Roadside hazard identification
- Knowledge of roadside clear zone requirements for the road segment
- Familiar with roadside design guidelines for the jurisdiction
- Safety procedures for work zones

Safety equipment like crash cushions and bridge railings require more thorough inspections where the inspector has to walk around the equipment and check if the foundation or anchoring has been damaged. Bridge railings and their inspections are a part of the regular bridge inspection programme. However it should be recognized that nearby structures like guardrail transitions and crash cushions connected to the bridge also have anchorage issues that must be investigated thoroughly.

Most roadside safety equipment – steel and concrete restraint systems – can be inspected using a “drive-by” inspection or patrols. Even minor damage can usually be recognized from a passing vehicle.

1.5 Data Collection: Repair Requirements / Estimation

It is important to describe damages to the safety equipment in a correct and comprehensive way in order to ensure that the repairs are done effectively. The repair crew prepare for repair activity based on the information reported for the damaged section. If damage is more extensive than anticipated (based on the damage description) the repair work might not be done effectively and a lack of sufficient materials can result in undesirable traffic delays.

Time

Date and time when the inspection took place shall be written down. If there was a known accident that caused the damage then the date and time when the accident occurred should be noted too.

Accident

If the accident that caused the damage is known to the police, a reference to the police report should be added to the description.

Location

The location of the damaged section must be identified. This is done by identifying the road section and how far into the section the damaged equipment is and which side of the road. The position coordinates should be consistent with the region's road inventory database. If possible, the location can also be identified with GPS coordinates to facilitate the use of digital maps and GPS navigation.

Damage

The description of the type of equipment that has been damaged, e.g. guardrail, crash cushion and terminal, and the full extent of damages must be clear. The severity of the damage and how it affects the road safety is necessary to know in order to have the appropriate repair response time. Safety equipment where the foundation or the anchoring is crucial for the safety performance should be known to the inspector so he can investigate the damage on these parts. This is important for example on crash cushions and bridge guardrails.

Pictures

Pictures of the damaged equipment and the surroundings facilitate later analysis and their value should not be underestimated. It is better to take too many pictures than too few and that is not a problem with today's technology.

1.6 Preventive Inspections

Routine inspections or patrols should not only inspect the road restraint systems and other safety equipment, but also identify other roadside elements in the clear zone and recovery zone, such as trees, rocks, steep side slopes as well as other features like commercial signs, stands etc. These elements affect the road safety and should be removed, replaced or protected with restraint systems when required. Therefore, the road inspector must recognize if these elements are hazardous if a vehicle leaves the roadway. Similarly, recovery zone elements like emergency lanes and hard shoulders should be clear of debris so that their performance is not reduced.

The inspector is primarily interested in finding and reporting changes to the road infrastructure since the last inspection. Some changes (growth of vegetation) are gradual and must be consciously reviewed so that small bushes do not gradually become roadside hazards. Also the other elements of IRS than road restraint systems should be reviewed (cleanliness and visibility of traffic signs, wearing of road markings).

Another task for preventive inspections is the identification of old designs / improperly installed equipment. It must be recognized that road safety infrastructure installed decades ago may not meet current standards or best practice guidelines and can be hazardous for road users.

1.6.1 Examples of hazard identification during site inspections

Unprotected Bridge Railings

Exposed bridge railings, see Figure 1.1, can represent a serious hazard to occupants of errant vehicles, where railings could spear vehicles. The impact into bridge structures would also be high, increasing the risk of serious injury to vehicle occupants.

Figure 1.1. Exposed bridge railings.

Recommendation:

The bridge railings and structures should be protected with safety barrier or crash cushions. The concrete bollards should be replaced with collapsible bollards.

Inadequate Restraint Systems

Impacts into inadequate passive safety devices on high speed roads can lead to high severity accidents. Problems typically occur when:

- Headwalls at some culverts close to the carriageway are not constructed with safe geometries or protected with safety barriers
- The lengths of safety barrier are insufficient to protect some bridge pillars and other roadside hazards, see Figure 1.1 and Figure 1.3
- Mature trees
- Gaps in central reserve barrier allowing out of control vehicles to cross to the opposite carriageway
- Temporary barrier sections that are not continuous segments
- Ramped ends of safety barriers that are not turned away from direction of travel, can result in vehicles being launched into structures, see Figure 1.2. This problem was identified in the RISER detailed accident analysis.

Figure 1.2. The length of the safety barrier would allow a vehicle to go behind the barrier and strike the bridge pillar.

Figure 1.3. Barriers before bridge are too short to stop vehicles from rolling down the steep embankment.

Exposed Support Structures

If a vehicle fails to negotiate the turn in Figure 1.4, it could run straight into the obstacles, resulting in a high severity impact.

Figure 1.4. Street furniture in a vulnerable position.

Recommendation:

When roadside inspections identify hazards due to older designs or inadequate protection, the site should be documented and the roadside design guidelines should be consulted to correct the deficiencies.

1.7 SUMMARY

The results of the RISER study indicate that an inspection programme is necessary for identifying maintenance activities. It is important that three types of inspections are identified:

1. **Safety inspections** - are designed to identify defects likely to create a danger to the road users
2. **Detailed inspections** - are designed for routine maintenance tasks not requiring urgent execution

3. **Safety patrols -** are a supplement to safety inspections on the higher priority motorways and trunk roads

Damage or repair issues arising from these inspections should be prioritised for their repair urgency. At least three categories should be used:

- **Level A** - requiring prompt attention, as the defect presents an immediate or imminent hazard to road users
- **Level B** - defects which if not treated will get worse and cause major maintenance works at a later date
- **Level C** – defects that can be divided further with various levels of repair response times. Their response time can be adjusted to fit into a routine maintenance programme.
- **Level D** – defects requiring no repairs but should be monitored

The frequency of inspections must be determined for local conditions. It is crucial that high traffic roads (motorways and national roads) are inspected daily while minor roads have weekly inspections. Specific infrastructure inspections should be adjusted to suit the equipment performance requirements.

Reports from inspections should be incorporated into a database with basic information like date, location, and references to police reports when available. Pictures of the damage should be stored when possible.

References

1 *Deliverable 01: Accident databases for collisions with roadside infrastructure*, RISER, Contract No. GRD2/2001/50088/RISER/S07.15369, 2004

2 Cottrell, B., *Field evaluation of highway safety hardware maintenance guidelines*, Transport research record 1163, Washington, D.C. USA, 1988

3 Lundkvist, S., *Condition assessment of road equipment, State of the art*, VTI, 2003

4 *Deliverable 07: Summary of maintenance and operational procedures for roadside infrastructure*, RISER, Contract No. GRD2/2001/50088/RISER/S07.15369, 2003

CHAPTER 2: DATA ANALYSIS

2.1 Objectives

The purpose of this chapter is to investigate the different resources available to road inspectors conducting preventive audits or black spot identification programmes on road sections open to traffic.

The usage of maintenance data, such as repair reports, for safety monitoring purposes is not widely reported. This chapter will demonstrate that the application of black spot methodologies to maintenance data can provide additional accident risk assessments for road sections and identify infrastructure weaknesses.

2.2 High Accident Rate Road Sections (HARRS)

2.2.1 Initial Considerations

Road accidents are not evenly distributed over the network. In various countries, research shows that the relation between the number of accidents and the traffic volume in a road section is not proportional. In other words, the accident rates vary in relation to the traffic volume in an imprecise way. In addition to which the source data (police reports) may itself lead to wrong interpretations (see RISER Deliverable 1 [1]).

Traditionally, a dangerous site is defined as a road section with an increased probability that an accident occurs in a particular location or that accidents that occur in a particular location result in serious casualties.

However, a high rate of accidents or a high rate of serious casualties in a particular road site during a short period of time are not the only indicators that this site may pose a high risk to road users in comparison with other road sites. In contrast to injury accidents, unreported accidents (such as those which result in minor damage to the vehicle), "near misses" (as evidenced by skid marks), or an accumulation of repair reports involving roadside furniture can point to a dangerous site for road users. All available information must be taken in account before making any conclusion. Temporary issues (road works, flooding, etc) should not initiate countermeasures that do not address the cause of the safety problem.

Accordingly, it is important to establish a method that enables road experts to identify locations with a high accident rate that are associated with a higher risk rate. This process may be complemented with the application of maintenance or road contractor data.

2.2.2 HARRS Criteria

One of the primary missions of road authorities is to focus their actions on road sections where road safety hazards are concentrated, known as High Accident Rate Road Section (HARRS) or "black spots".

Each road administration has developed its own black spot definition depending on various criteria presented in Table 2.1 [2]:

Table 2.1. Black spot definition in some European countries.

Country	Black spot definitions
Austria	A junction, an intersection or a part of a road stretching up from a few metres to a length of 250 m where at least three similar accidents with personal injuries happened within the last three years
Belgium	A 500m road section where 5* D + 3*Z + 1* L > 15 (D = number of persons killed, Z = severely injured persons, L = light injured persons) over three years
Finland	Currently, Finland has no systematic black spot identification programme
France	France has three levels of accident cluster sites (ZAAC): Level 1: sections that on 850 m, concentrate at least 4 injury accidents and at least 4 seriously injured persons in 5 years Level 2: sections that on 850 m, concentrate at least 7 injury accidents and at least 7 seriously injured persons in 5 years Level 3: sections that on 850 m, concentrate at least 10 injury accidents and at least 10 seriously injured persons in 5 years
Germany	Road section of 300 metres With more than 5 similar type accidents within a 1-year accident type map With more than 3 accidents within a 3-year accident type map
The Netherlands	Usually an intersection At least ten accidents or dangerous situations in total or At least five accidents or dangerous situations with some common characteristics In a period of three to five years
Spain (by region)	*Andalusia* Road section of 1 km More than 5 accidents with injuries in 1 year or more than 2 people killed in the same time period More than 10 accidents with injuries in 3 years or more than 5 people killed in the same time period *La Rioja* Road section of 1 km Five or more accidents causing injuries during the last 3 years, or 3 or more accidents causing injuries in one of the last 3 years (one of the accidents must involve at least a person killed) *Madrid* Spots where, during the year of study, 3 or more accidents happened *Valencia* Spots (including the previous and the following 100m) with 3 or more accidents during the last 3 years
Sweden	Number of accidents on a spot or 10-50 km stretch is more than 20 during a certain period (normally 3 or 5 years)
UK	A location of three hundred metres A location where the sum of road accidents is higher than twelve in three years

When summarising the definitions from all countries, the following are used for defining a black spot:

- the number of accidents or reported dangerous situations
- the length of the road section
- the time period considered

One aspect that has been left out is traffic volume for the given road section. This is of particular importance as a road accident on a minor artery carrying 1000 vehicles per day does not carry the same statistical weight as an accident on a major thoroughfare with 15000 vehicles per day and more.

2.2.3 How Black Spots are Created

Problems related to road safety can originate from decisions made or by actions done during various phases of development and operation of the road network. Examples of this phenomenon are shown in Table 2.2 below:

Table 2.2. Origin of road safety problems in various phases of development and operation of the road network.

Phase	Example
Planning	The separation of mobility and accessibility functions through an adequate hierarchical improvement of safety conditions.
Project	Roads with high standards are safer. However road design should not only rely on standards, but should be based on sound engineering judgement.
Construction	Layout problems can arise from construction errors, thus decreasing safety.
Maintenance and operation	Different problems can be faced such as, e.g. bad set of traffic lights, disproportions between the carriageway and the hard shoulder, proliferation of points of access, inappropriate signing maintenance, lack of surface upkeep, etc.

2.3 Black Spot Identification

2.3.1 Period of Observation

An important parameter for developing a reliable identification of road sections having a statistically significant high accident rate is the determination of the time period in which the analysis is made. Consequently, in any attempt to identify “black spots”, the following points should be considered:

- The analysis period must be long enough to yield representative accident samples. Following that principle a large number of studies have been made and it has been generally agreed that in most cases a period of three to five years is sufficient to guarantee the reliability of the analysis
- For the identification of road sections where sudden changes in the accident rates have occurred, it is useful to analyse short time periods of one year or even less, in order to detect specific reasons and mechanisms causing accidents
- To avoid distortions due to seasonal variations, it is important to use time periods of several years
- After four or five years of delay, accident and/or maintenance data may not be representative of the current road and traffic conditions, or of the development of adjacent activities and of user behaviour, etc. Therefore, it is important to use, when possible, two periods of analysis. The first period of three to five years will ensure the reliability of the sample. A second period

of one year will allow detecting changes in the accident rates caused by new factors

2.3.2 Identification Methodologies

Once the relevant traffic and accident data have been collected, technical identification methods based on the following points should be used:

- The accident risk rates selected for the identification of HARRS must be based on the calculation of average rates of networks with similar characteristics
- The average accident risk rates have to be calculated for each interval of average daily traffic that represents the different traffic categories
- Distinction should be made between the different road categories (motorway, road with limited access, single carriageway, etc.) between the various types of areas (built-up areas, outside built-up areas, etc.) and between road sections and intersections
- It is important to use data of at least three consecutive years. As a consequence, a database is necessary to store and to use the data in an appropriate manner
- The addition of maintenance data that can identify the number of "property damage only" accidents will increase the amount of data and should be used as a complement to compare the accident rates on similar road sections

Various data which need to be collected as part of the HARRS identification procedure is summarised in Table 2.3 below [3]. Additional maintenance related details have been included in bold.

Table 2.3. Data needed in the HARRS identification procedure.

Type of data	Example
Network data	▪ List of the safety characteristics of the road (geometry, lateral obstacles, road surface properties, etc.) ▪ Legal speed ▪ Video of the network (if available) ▪ **Copies of any repair reports involving road safety equipment or roadside furniture**
Accident data	▪ Type of accident (head-on collision, run over, etc.) ▪ Severity ▪ Determinant factors of the accident ▪ Circumstantial factors: weather and lighting conditions ▪ Crash diagram ▪ Copies of the reports of the accidents occurred on the road section
Traffic data	▪ Database of the traffic characteristics of the road section ▪ Intensity of the different movements ▪ Observed speed ▪ Road and/or intersection capacity ▪ Traffic conflicts ▪ Distance between vehicles ▪ Length of queues ▪ Visibility distance ▪ Pedestrians and bicycles traffic ▪ Other activities

2.4 Data Analysis

2.4.1 Phase 1: Definition of the Context

Road user behaviour considered as safe is not constant as, among other factors, road user behaviour depends on the road characteristics, the individual conditions of the driver and the traffic context. In the same way, the perception of a road defect also varies as this is related to the road site characteristics, the environment and the road operation. Therefore, the first step of a "black spot" analysis is to define the location environment and its use. This information will serve to determine if a road characteristic is safe or not and, to define possible solutions.

The typical operational road classification distinguishes three types of road networks:

1. Transit or arterial network related to long distance trips
2. Local network related to local trips
3. Distribution network, linking the previous ones

On road sections where accessibility and mobility functions are not divided, the level of safety decreases as conflicts between two user categories emerge: the slow users entering the carriageway and the fast users passing by. This situation can be explained by the degradation of a road, initially designed with a particular mobility objective, associated to the loss of development control of the access. Nevertheless, it can also be the case that residential areas, business centres, etc. have been developed on the sides of the road and that this development has a negative impact on the safety level of the site. Consequently, the accessibility and mobility functions of a road should be clearly separated.

2.4.2 Phase 2: Data Collection

Before visiting a location, it is necessary to analyse in detail all the accident and maintenance reports available. The aim of this analysis is to check if common causes of accidents are detected. The definition of these abnormal accident causes directs the research to the factors responsible for these accidents. In addition, it allows developing appropriate solutions. Thus, this first analysis of the accidents reports often shows an unusual frequency of one or several accident factors. Consequently, it provides a direct guide of what has to be studied during the in-site investigation.

Accident reports contain a great amount of information that can be used to detect problems related to road infrastructure deficiencies. The period in which the data are analysed depends on the conditions of the road location. Generally, three to five years of data are sufficient for the analysis. However, the analysis of roads with a low traffic density, which consequently have a low accident frequency, probably requires more time in order to find the determinant accident factors. Thus, if the accident frequency is high, it may be sufficient to study only one year of data to obtain a clear picture of the road location's accident characteristics. Further, the conditions of the road location should not have been modified during the time period chosen for the analysis (no layout modifications, no traffic light installation, etc.).

The incorporation of maintenance reports into black spot analysis is one method of linking the routine operation of a road with the upgrading requirements triggered by a succession of accidents. A maintenance "black spot" can be a trigger to redesign a specific element of the road infrastructure due to an extraordinary amount of collisions. A maintenance "black spot" may also arise if a specific infrastructure element is repeatedly performing unsatisfactorily as documented in repair reports. Both the frequency and severity of maintenance activities can be treated as an equivalent to accident frequency and severity when analysing the safety performance of a road section.

It is common practice to prepare summaries that are of great use during the rest of the diagnosis process. The most frequently made ones are:

- **General crash chart** - is the most frequently used summary to analyse a dangerous location. It is a graphic representation of the accident, which includes location layout and orientation, path of each vehicle, precise location of each accident, type of collision (lateral, frontal, etc.) and accident severity
- **Bar charts** - show several characteristics of each accident occurring on the same spot in the form of a table. As a consequence, bar charts help to identify frequent types of accidents
- **Comparison tables** - compare the frequency or the proportion of accident characteristics of a specific location with the standard values of the same characteristic for similar locations

Where possible, the following items will be analysed in the data collection phase:

- Speed study
- Skid resistance study
- Analysis of traffic conflicts
- Analysis of infrastructure repairs
- Traffic capacity analysis
- Study of traffic light phases
- Study of the lighting
- Study of repeated skid marks
- Performance of the roadside safety devices

2.4.3 Phase 3: On-Site Investigation

The on-site investigation phase includes:

- The familiarisation with the location to obtain the drivers' point of view
- A very detailed observation of road and traffic characteristics, and road user behaviour

The main objectives of the on-site investigation are:

- To find the road characteristics explaining why accidents occur in that spot
- To identify road defects that did not contribute to any accident but are recommendable to count as potential elements of risk
- To identify road defects that contributed to the increase of the accident rate and have not been detected by previous studies

When a road expert arrives at the spot that he will be studying, he should approach this spot from all possible directions by car, following the normal traffic speed in order to obtain the drivers point of view.

If the analysis of the accident or repair reports shows that collisions occur during specific time periods or are due to some particular road conditions, then, the road experts should visit the studied location at the right moment in order to observe these special situations (like during peak time, at night, during summer, during the weekend, during rainfall or fog, etc.). In addition, some photographs should be taken at regular intervals or a video of the location should be made, describing the layout, the road user behaviour and the assistance to the drivers.

During the on-site investigation, the road expert must identify all the existing elements that may contribute to increasing the accident risk. An element of the accident risk is defined here, as being any physical feature of the road or its environment, obstacle or device that can be measured and presents an accident risk or is an aggravating factor of a potential accident.

2.5 Summary

The lack of maintenance data in a form suitable for analysis limits the application of the Black Spot approach in the RISER project. Therefore, further recommendations for the analysis and interpretations of maintenance data are not possible. However, the local use of Black Spot analyses can be adapted to incorporate maintenance data. It is crucial that all maintenance data should be stored in a suitable computer database that will allow processing.

References

1 *D01: Accident databases for collisions with roadside infrastructure*, RISER, Contract No. GRD2/2001/50088/RISER/S07.15369, 2004

2 *Report on infrastructure safety management*, European Commission, 2003

3 *Guidelines to black spot management*, European Union Road Federation, 2003

CHAPTER 3: REPAIR PLAN

3.1 Introduction

The repair plan is a document with regulations, rules, and/or guidelines for when and how certain maintenance activities at the road shall take place. The focus of this section is on the roadside area. The maintenance activities may vary from small adjustments of signs or sign poles up to major repair works and component replacements on road restraint systems.

The activities could be:

- Provisional repair or warning signs securing that the road is safe enough to allow traffic until the main repair activities will take place
- Repair of roadside area components
- Replacement of roadside area components

An example of the importance of a repair plan was collected in the RISER detailed database. On a single carriageway road, the driver lost control on a bend, see Figure 3.1. The vehicle left the road to the nearside, and rolled over into a 1.32m downward slope into a field. During the rollover, the vehicle did travel over (but did not contact) a section of barrier which had already been damaged in a previous accident, but had not been repaired, see Figure 3.2. From looking at the photographs, it is possible that if the barrier had not been damaged, the vehicle may have impacted and been contained by the barrier and therefore not rolled into the roadside.

Figure 3.1. Bend where vehicle ran of the road.

Figure 3.2. Damaged barrier in bend.

3.2 International References

The references collected and used for RISER deliverable D07 [1] includes a variety of sources with different level of details and different levels of status as a regulation. Enclosed is a list of different kinds of sources:

- CEN standards
- National standards

- Guidelines
- Advice notes
- Technical manuals
- Agency reports
- Agency handbooks
- Regulations
- Recommendations

3.3 Summary of Practices

It is obvious from the summary of standards and guidelines in D07 that the United Kingdom is the country most regulated by national standards. Sweden, France, Spain, Germany and Finland have some guidelines for both inspections and repair whereas the Netherlands only shows guidelines for inspections.

Potentials for setting up standards and guidelines are obvious for several of the countries and some of the presented guidelines could very well serve as examples for development of national standards or if in the case the national road authority prefer a regional or local standard. It should be noted that the requirements for formal standards is dependent on the organization responsible for the actual work. For example, subcontracting of maintenance activities will require legal contracting documents that specify a level of performance standard for the services.

The results of the exercise indicate that only road restraint systems (guardrails, safety fences, etc) are explicitly addressed in existing documents. Other road infrastructure elements (trees, rocks, ditches) that also affect the road safety are not explicitly discussed in the maintenance policies. Future development of maintenance and operations procedures can apply the existing experience with road restraint systems and apply them to all roadside infrastructure elements.

There are variations between different countries but normally different repair categories are defined related to the risk that the damage will cause more accidents. It is also considered whether the damage will be worse if it is not attended to shortly. The time for attendance, after an accident or after that the damage is reported, is found to be between 1 hour and several days or even weeks.

The time until the repair work shall start varies from 1 hour to 4 weeks or up to the periodic maintenance, again related to the level of damage and the judged risk as described in Chapter 1.

3.4 Preconditions for the Repair Plan

For producing the repair plan different kinds of information are used:

- The reports from regular inspections
- The report from inspections after an accident
- Data from the periodic maintenance plan

It is supposed that the inspectors in the two first cases will produce a report containing information of the damage and how hazardous the situation is. This data collection and analysis, also mentioned in the chapter on road inspection, is important for the decision of what shall be done and when. If a maintenance activity already is planned in the periodic maintenance plan this should be considered in order to have a proper timing for the repair work.

3.5 Frequency of Repair

Time to Attendance

It could be discussed if the road inspector or inspection group shall be able to cater for securing the place of accident to avoid occurrence of more accidents. If they shall, the team needs more resources in form of personnel and material. This will of course have an impact of the cost for having the team stand by. Also quality of the repair might be lower than if it is done by a specialized repair team.

Time until Repair

This will, of course, be based on the analysis of the damage and the risk assessment done by the inspectors. The cost for repair can be reduced if a specific repair can be scheduled together with other similar activities nearby. Thus the whole procedure for inspections and repair can be optimised.

The component replacement process will also be less complicated if the repair schedule can take into account the different manufactures of equipment.

The Time of the Day for the Repair Work

The maintenance cost and road user cost will of course be related to when a certain activity on or nearby the road is taken place. Also safety and environmental issues for the labour must be considered. At peak hours the labour costs are small but the delays for the road users will be high. Also the risk for the labour and the traffic is higher at these hours as well as the pollutant emissions from the traffic are more extensive.

At hours outside normal work time the labour will cost more but the disturbance of traffic and from traffic is less. The road category can then be used for decision of time schedule for the work.

3.6 Criteria for Component Replacement

There are criteria for beams, posts, anchors and fasteners. Only components and installation methods that are in accordance with the criteria (CEN-standards, national guidelines etc.) should be used. The components should not have visible cracks or stress raiser and be free from corrosion. Consultation with manufacturers and suppliers is necessary to develop the proper component replacement policy.

3.7 A Framework for the Repair Plan

A fixed response time is recommended when a contractor is responsible for the repair. A fixed response time means that the response time easily can be derived from a rule system e.g. a flowchart. A variable response time is the case when an expert decides for every case what a proper response time is for the specific case. When it is up to the contractor to make the choice, there is a risk that the working situation and available personnel will have an impact on the choice. The flowchart shown below is rule based using the response time before repair.

The response time can be 1, 3 or 24 hours, 5, 10, 20 or 30 days or until the next available periodic maintenance occasion.

The response time for a temporary repair activity is dependant on:

- how hazardous the situation is
- if the damage will become worse if it is not attended to
- when the damage is reported
- how the damage affect traffic operation

It is important to note that the temporary repairs made when first attending the scene may only require that the scene is cleared of debris to restore normal traffic operation.

The permanent repair response time depends on the risk for a new accident at exactly the same spot. Of course this depends on the situation and the traffic flow as well as the speed limit. The permanent response time assumes that a temporary repair has been performed.

The categories in the flowchart, in Figure 3.3, can be defined for every item in the roadside area and also be adjusted to the current economic situation in order to optimize the use of funds for road maintenance.

It is important that individual road operators or road authorities tailor Figure 3.3 to their local needs. To avoid the wrong application of this figure, the time critical events in categories A and B are not explicitly specified. Some suggested values for these times are X=1 hour for hazardous sites during working hours, Y=3 hours for off-peak times, and Z=24 hours for damage that quickly degrades safety.

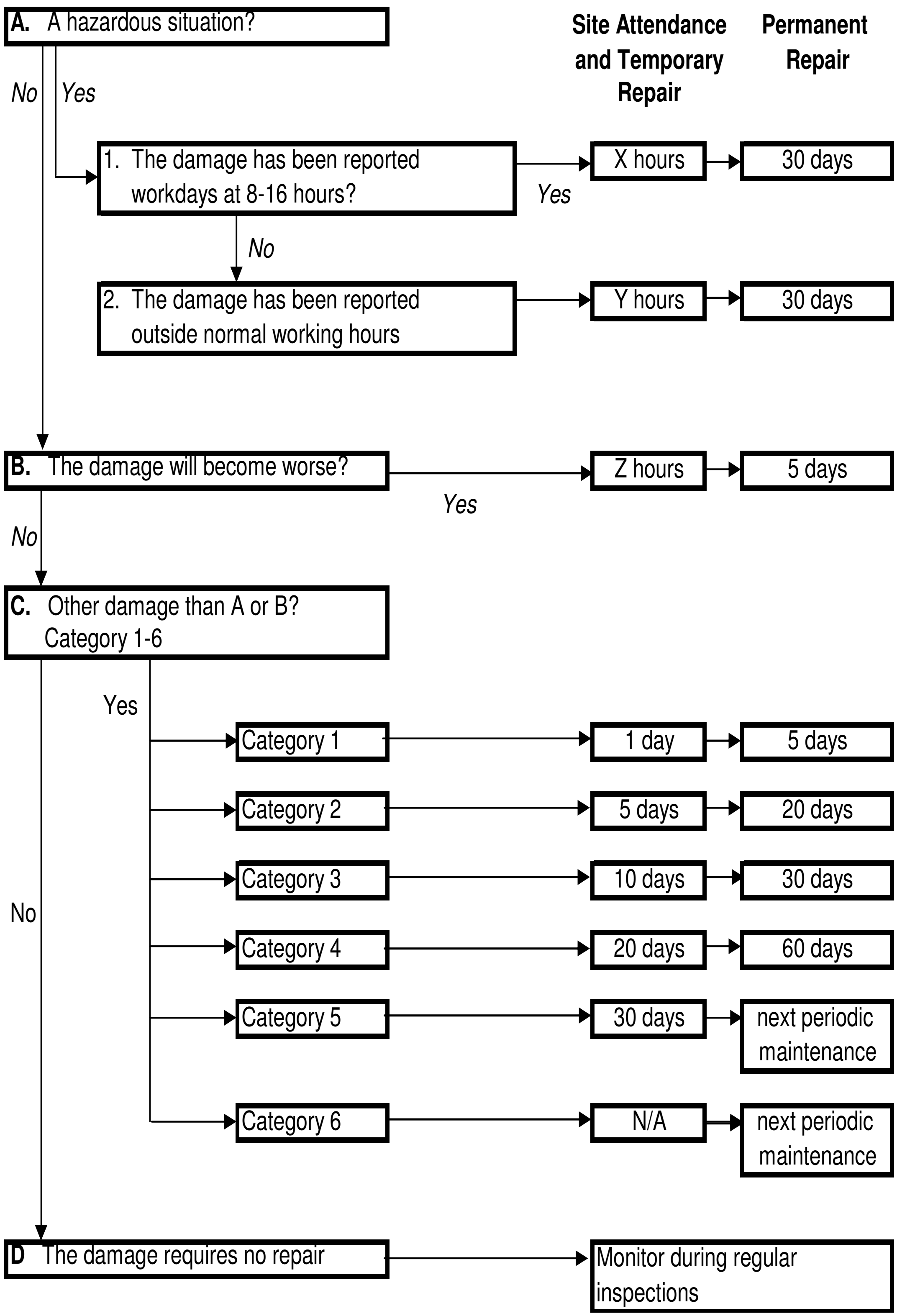

Figure 3.3. Flowchart for choice of response time (temporary repair) and time until repair.

This flowchart is closely related to the damage levels discussed in Chapter 1. Examples of damages in different levels and their respective response time are presented in Table 3.1. The response time is for temporary repair, but in some cases the permanent repair should be undertaken directly because the situation is extremely dangerous for the road users.

Table 3.1. Example of different damage levels and their response times.

(Courtesy of Rod Troutbeck, Queensland University of Technology, Brisbane Australia.)

Description	Damage Level	Response Time	Picture
Damaged guardrail on a bridge embankment	A	1 h	
Bridge rail attachment posts have corroded and the concrete covering has spalled away	B	24 h	
Damaged guardrail posts	C	7 days	

3.8 Defined Repair Notification Process

There is no known well defined repair notification process. Often the repair work is stored as invoices from contractors together with a minor description of the work done. As the information is only in paper form and not digital, a systematic analysis is difficult to do and the cost of the repair activities are not easily overviewed.

Assuming that the report from the inspectors contains a digital description of the damages, digital photos of the damages, a photo of the site giving an overview of the environment and the location described by coordinates (consitent with the road inventory database or from GPS coordinates), we will have a complete set of data. The maintenance activities can then be added and put into a database. This database would be useful for analysis of both accidents and maintenance procedures and costs.

3.9 Summary

There is a broad variation in the use of standards for repair plans between the participating countries in this study. We have to assume that new member states in the EU also will have different standards or no written standards or guidelines at all. A recommendation could be that the flowchart presented in Figure 3.3 could serve as a guideline for maintenance activities and that each country can define the different categories 1-6 in alternative C according to available road maintenance funds. A developed economy may then result in an upgraded category for a specific type of damage.

The alternatives A and B are applied for safety reasons and to avoid fast capital depreciation, when the damage is rapidly becoming worse.

The use of a digital database with photos and inspection and maintenance history will facilitate the choice of action as well as an analysis over time.

References

1 *D07: Summary of maintenance and operational procedures for roadside infrastructure*, RISER, Contract No. GRD2/2001/50088/RISER/S07.15369, 2003

CHAPTER 4: TRAINING

4.1 Current Availability of Training

The availability of national-level structured training programmes for those working in the area of highways maintenance appears to be fairly limited across Europe (see RISER Deliverable 7 [1]), with the exception being in the UK:

- **UK** - Safety barrier erectors are expected to have completed a training course for the type of barrier they are required to work on [2]. Training requirements are also outlined in the UKAS published document 'National Highways Sector Schemes for Quality Management in Highway Works' (see reference [3] for further details). Courses are approved by the 'National Fencing Training Authority' (now incorporated into Lantra Awards [4], a subsidiary of Lantra [5]). Training courses are also provided for supervisors, clerks of work, inspectors, technicians and engineers, but no further details are given. The basic course covers Tensioned and Untensioned Corrugated Beam, Open Box Beam and Double Rail Open Box Beam Barriers. Additional courses cover wire rope fences, Rectangular Hollow Section barriers, temporary barriers and crash cushions. Other courses include:
  - 'Appreciation' courses for supervisors, clerks of work, inspectors, technicians and engineers
  - Incident Response Procedure courses for Wire Rope safety fences
  - Courses for inspectors of safety restraints
  - Courses for the maintenance of temporary traffic management on high speed roads
- **Sweden** - The road sectors education centre (VUC) run courses for maintenance clerks, inspectors, technicians, engineers and road workers (SRA)
- **Spain** - The road contractor itself trains its workers
- **The Netherlands** - Two days training is provided by the Construction Department at Rijkswaterstaat, which covers the inspection of specific items and quality systems training. Maintenance inspections are only carried out by those who have undertaken this course
- **Germany** - No specific training is given for maintenance inspections, but is for installation of road restraint systems

4.2 Importance of Training

When introducing harmonized European maintenance and operations guidelines, it is essential to include a structured training course to cover the procedures outlined in the guidelines. This will ensure that these procedures are undertaken correctly across Europe.

4.3 Who Should Be Trained?

Personnel who are involved in all aspects of maintenance and operations of road safety equipment and infrastructure should undertake training to enable them to understand all the issues involved. This includes:

- Inspectors
- Supervisors
- Engineers/Designers
- Technicians
- Road workers
- Safety barrier erectors
- Clerks of work

4.4 What Should the Training Involve?

The training should involve the following areas to ensure that those working in maintenance and operations have a thorough understanding of vehicle restraint installation procedures, the importance of undertaking inspections of road safety infrastructure and ensuring relevant repair work is carried out.

- An overview of road and roadside infrastructure for hazard identification:
  – Restraint systems - steel safety barriers (all types of steel safety barriers that exist on national road network), wire rope fences, concrete barriers, crash cushions, bridge parapets, old design barriers
  – Road markings - painted markings, tactile markings/studs (e.g. rumble strips)
  – Traffic signs and lighting/utility poles - frangible and non-frangible
  – Other 'changes' in the roadside which may affect safety - for example, tree and vegetation growth, rock falls
- An understanding of the installation of road restraint systems and frangible posts/poles, plus an understanding of the use of road markings
- Principles of road safety auditing and risk assessment and their use as a method of inspecting roadsides for hazard identification
- Categorisations of defects and damage
- Types of inspections and frequencies
- Reporting and recording of inspections
- Procedures for repair operations on roadways
- Case examples of good and bad maintenance and operations procedures, specifically highlighting road safety issues
- Additional information of use to specific jobs in maintenance and operations

The depth of information that is covered in each of these areas will depend on the type of personnel being trained and the nature of their work. For example, safety barrier erectors need to be trained to have an extensive knowledge and understanding of the installation of the types of safety barriers they are to work on, as it is an integral part of their job. However, engineers will only require a general awareness of these procedures, to aid in their identification of damage and repair issues for safety barriers. Inspectors require the most training as they should be able to identify all the road safety issues at an accident location. For example a collision with a rigid object could result in a vehicle fire that affects the road marking. Thus the inspectors should identify any repairs necessary for roadside structures but also specify which road markings need to be temporarily (and eventually permanently) restored.

Therefore, it should be ensured that the correct balance of information is included in the training programme developed for each type of personnel.

4.5 Duration and Frequency of Training

In the UK, safety barriers erectors are required to have completed a training course for the types of barrier they are required to work on. This course takes 5 days to complete.

Additional courses are available if safety barrier erectors subsequently are required to work on other types of barriers, such as wire rope (2-3 day course), RHS (1-2 days), temporary barriers (1 day) or crash cushions (not specified).

Appreciation courses for inspectors, engineers, clerks of work, installation designers and supervisors takes 5 days.

Inspectors of safety fences only are required to undertake a 3 day course to be able to undertake inspections.

Therefore, a basic training course which covers the basics of all of the above areas would need to be a minimum of 5 days, with additional days for areas of particular importance to specific personnel working in maintenance.

Refresher courses should generally be taken approximately every 5 years.

4.6 Training 'Accreditation'

The training should be accredited by a recognised impartial body of good standing within the road maintenance industry. In the case of the UK, it is 'Lantra' and 'Lantra Awards'.

4.7 Qualifications

Personnel working in safety barrier erection and traffic management schemes in the UK hold an ID-style card for each course they have attended and successfully passed, which they must have with them on site at all times. Those who successfully complete and pass maintenance inspectors courses generally receive a certificate of competence instead of a card.

It is recommended that delegates attending core training courses, add-on courses and refresher courses should receive a certificate of competence demonstrating attendance on the course and the "passing" of either a practical or written assessment.

For other courses which are less critical to the competent undertaking of the work, but are still of an informative nature, it is recommended that delegates simply receive certificates of attendance.

Finally, in the UK, there is a need for all professionals to demonstrate that they are up to date with continuing developments in the field of road maintenance. Therefore, it is important for professionals to keep a portfolio of their training history which shows their areas of expertise and lists their qualifications.

4.8 Summary

A training programme for roadside infrastructure elements should be part of every national road safety policy. As identified previously, different categories of staff should participate in some level of training including inspectors, supervisors, road workers, office support staff to name a few. The level of training will be dependent on the role of the employee. Important topics to be covered include (but are not limited to):

- An overview of road and roadside infrastructure for hazard identification
- An understanding of the installation of road restraint systems and frangible posts/poles, plus an understanding of the use of road markings
- Principles of road safety auditing and risk assessment and their use as a method of inspecting roadsides for hazard identification
- Categorisations of defects and damage
- etc.

Training should be provided for new employees with refresher courses provided for individuals with training intervals suiting their job requirements. To date the UK has the best training system identified in the European Union and should be used as a reference.

References

1 *D07: Summary of maintenance and operational procedures for roadside infrastructure*, RISER, Contract No. GRD2/2001/50088/RISER/S07.15369, 2003

2 *BS 7669-3:1994. Vehicle restraint systems – Part 3: Guide to the installation, inspection and repair of safety fences*, British Standards Institution, 1994

3 *National highway sector schemes for quality management in highway works*, United Kingdom Accreditation Service (UKAS)
The schemes of most relevance are:
- Scheme 2B - For the supply, installation and repair of vehicle restraint systems, 2002

- Scheme 5B - For the installation of parapets for road restraint systems, 2005
- Scheme 7 - For the application of road marking materials and road studs to road surfaces, 2003
- Schemes 8, 9B & 10 - Installation and maintenance of highway electrical equipment and road traffic signs, 2005
- Schemes 12A, 12B, 12C and 12D focus on the installation, maintenance and removal of static temporary traffic management on motorways, high speed dual carriageways, rural and urban roads, and also mobile lane closure traffic management, 2005

4 Lantra Awards Accreditation Service: http://www.lantra-awards.co.uk

5 Lantra: http://www.lantra.co.uk/

CHAPTER 5: CONCLUSIONS

A maintenance and operations programme for roadside infrastructure has to involve all the topics presented previously. Inspections, data collection and analysis, training, and a repair plan are all necessary to have a long term safe and sustainable road network. The inspection part of the programme is necessary to achieve a high level of safety for all users on the road network. The frequency of inspections must be determined for local conditions. It is crucial that high traffic roads (motorways and national roads) are inspected daily while minor roads have weekly inspections as a minimum. Infrastructure specific inspections should be adjusted to suit individual equipment performance requirements. Damage or repair issues arising from inspections or from other sources, e.g. police or the public should be prioritised according to their repair urgency. All repair works are planned in a repair management programme in order to find the most cost and logistical effective way to perform the repair work within the repair time limit. It is important that repair times match the road section needs so that traffic safety is not jeopardized.

There is a broad variation in the use of standards and guidelines for maintenance and operations among the countries in the EU. A recommendation could be that the flowchart presented in Chapter 3 could serve as a guideline for repair activities and that each country can define the different subcategories according to their available road maintenance funds and regional requirements. A developed economy can then upgrade categories for specific types of damage and integrate renewal programmes.

The use of a digital database with photos obtained from inspection and maintenance activities will facilitate analyses of the road infrastructure performance and allow for better planning of investments of equipment and human resources. At the moment there is a lack of maintenance data in a suitable form suitable for these analyses as well as limiting the application of the Black Spot approach proposed in the RISER project. However, the local use of Black Spot analyses can be adapted to incorporate maintenance data.

A training programme for roadside infrastructure elements should be part of every national road safety policy. Staff involved in the road maintenance sector should participate in some level of training suited for their involvement. Inspectors, supervisors, road workers, office support staff should all be provided initial training as well as refresher courses depending on the role of the employee.

The management plan for maintenance and operation is part of an overall road safety management plan and is strongly connected to design guidelines being applied by the national authorities. The close interaction between design and maintenance guidelines is obvious and will influence the functional level of the road network itself.

The increasing tendency to Public Private Partnerships (PPP) and private ownership of motorways transfers road safety from public to private responsibility. This may result in improving or reducing the level of maintenance and operations for the road in question and we have to pay close attention to this challenge. Harmonised European best practices for maintenance and operations are the one way of ensuring that road safety is guaranteed regardless of road owner, operator, and user.