SAFER ROAD INFRASTRUCTURE

28 September 2011 (am)

TECHNICAL COMMITTEE C1

INTRODUCTORY REPORT

CONTENTS

1. Contents 3
2. Executive Summary 3
2.1. Human Factors in Road Architecture – the System Approach 4
2.2. Deficiencies in Urban Roads – the Perspective of Vulnerable Road Users 4
2.3. The Linear Settlement Disaster for Vulnerable Road Users along Interurban Roads 4
2.4. Methods for Road Safety Impact Assessment (RSIA) 4
2.5. Work Zone Safety – a Growing Issue for Emerging Countries 4
3. Members who Contributed to this Report 4
4. Human Factors in Road Architecture – the System Approach 5
4.1. The Traditional Approach 5
4.2. The Human Factors Approach 6
5. Deficiencies in Urban Roads – the Perspective of Vulnerable Road Users 9
5.1. Introduction 9
5.2. Reasons for Deficiencies from the Perspective of Vulnerable Road Users 9
5.3. Typical Deficiencies in Urban Roads in Developed Countries 11
5.4. Typical Deficiencies in Urban Roads in Developing Countries and Countries in Transition 12
6. The Linear Settlement Disaster for Vulnerable Road Users along Interurban Roads . 13
6.1. Introduction 13
6.2. The Counter Strategies 13
6.3. Solutions for Deficiencies 14
6.4. References 16
7. Methods for Road Safety Impact Assessment (RSIA) 16
8. Work Zone Safety – a Growing Issue for Emerging Countries 18
8.1. Introduction 18
8.2. Statement of Issues 19
8.3. Results of an International Survey on Improvements in Safe Working on Roads 21
8.4. Road Safety – Human Factors Basics 21
8.5. Drivers Actions and Engineering Elements in Work Zones 22
8.6. References 23

1. CONTENTS

Technical Committee C1: Safer Road Infrastructure was tasked to deliver outcomes in the following four strategic areas:

- Human factors in road design that influence driver behaviour:
    - Examine how key human factors that affect road user behaviour can be translated into engineering characteristics and road safety design policies.
    - Undertake a review of other guidance on human factors especially regarding vulnerable road user behaviour in road design standards.
- Safe design for roads in urban areas:
    - Consider recent changes to design guides for urban roads that promote improved road safety.
    - Review safe road design in urban areas using segregated road space for the needs of vulnerable road users and public transport.
    - Compare and evaluate design provision for low speed roads in residential areas
- Design improvements for vulnerable road users:
    - Assess design guidance on safe design for vulnerable users.
    - Select design examples of good practice for the needs of vulnerable road users along those interurban roads to improve the situation in so called “linear settlements”.
- Improvements in safe working on roads:
    - Assess approaches aimed at improving the safety of road workers.

The papers presented in this session encompass the following specific elements of the strategic areas listed above:

- Human factors in road architecture – the systems approach.
- Safe design for urban roads.
- Vulnerable road users and linear settlements – coffin roads.
- Methods for Road Safety Impact Assessment (RSIA).
- Guidance to improve safe working on roads.

2. EXECUTIVE SUMMARY

The most important event that occurred during the committee’s term was the March 2010 UN Resolution of the General Assembly proclaiming the period 2011-2020 as the Decade of Action for Road Safety, with the goal of stabilising and eventually reducing the number deaths and injuries. This formalised a declaration adopted at the First Global Ministerial Conference on Road Safety: Time for Action, held in Moscow in November 2009.

Objective 4 of the declaration is to “Make particular efforts to develop and implement policies and infrastructure solutions to protect all road users, in particular those who are most vulnerable”. The World Health Organisation’s Global Status Report on Road Safety indicates that vulnerable road users comprise the most significant proportion of the annual 1.3 million victims in road traffic. Road design and operations require a complex system approach to effectively achieve the desired road safety outcomes of the infrastructure. But what are the rules for safe roads?

The papers presented in this session encompass the following specific elements of the strategic areas:

2.1. Human Factors in Road Architecture – the System Approach

After decades of trial and error seeking to adapt road users to the technical elements of the transport system (vehicles and roads), it has now been established that the opposite is more effective: adapt the technical subsystems to road users' abilities and limitations. PIARC's road safety technical committees have utilised a human factors system approach for a decade. This session will demonstrate how the knowledge about human factors should be integrated into geometrical standards for urban and interurban roads.

2.2. Deficiencies in Urban Roads – the Perspective of Vulnerable Road Users

The PIARC Road Safety Manual contains excellent technical sheets for interurban roads, but guidance for urban situations is lacking. The session will fill this gap.

2.3. The Linear Settlement Disaster for Vulnerable Road Users along Interurban Roads

Linear settlements are crucial safety problems responsible for the over representation of vulnerable road users in traffic crashes. Urban development, land use planning and access control play a decisive role in road infrastructure safety. The session will demonstrate examples from different continents and provide proposals to address the issue.

2.4. Methods for Road Safety Impact Assessment (RSIA)

Development policies demonstrate the significant impact that master plans can have on road safety outcomes. In a similar vein to environmental impact assessments, road safety considerations should be integrated into planning from the very beginning. PIARC is proposing to develop Road Safety Impact Assessment Guidelines (RSIA) in the forthcoming period. This session will outline some improvements to the Road Safety Audit and Inspection Guidelines and discuss the role of infrastructure safety management, which will be an important chapter in the new PIARC Road Safety Manual.

2.5. Work Zone Safety – a Growing Issue for Emerging Countries

Work zone safety is another crucial infrastructure safety issue, particularly in emerging countries. Many severe traffic crashes occur at road construction sites, because drivers are not prepared and workers are not well protected. PIARC has taken the initiative to create a new guideline for the safe performance of road works, which will be included in future amendments to the Road Safety Manual.

3. MEMBERS WHO CONTRIBUTED TO THIS REPORT

Hans Vollpracht, Germany
Jürgen Gerlach, Germany
Roberto Llamas, Spain
Philip Vaneerdewegh, Belgium
Lise Fournier, Canada-Quebec
Jon Douglas, Australia
Sibyelle Birth, Germany
Mike Greenhalgh, UK
Beth Alicandri, USA
Åke Larsson, Sweden

Roberto Llamas Rubio, Spain
Jaakko Klang, Finland
Bernhard Lautner, Austria
Stanislas de Romémont, France
Aditya Bahadur, India
Uroš Brumec, Slovenia

4. HUMAN FACTORS IN ROAD ARCHITECTURE – THE SYSTEM APPROACH

The UN-Global Plan for the Decade of Action for Road Safety defines the framework for the Decade of Actions in Chapter 4 as follows:

"The guiding principles underlying the Plan for the Decade of Action are those included in the "safe system" approach. This approach aims to develop a road transport system that is better able to accommodate human error and take into consideration the vulnerability of the human body. It starts from the acceptance of human error and thus the realization that traffic crashes cannot be completely avoided. The goal of a safe system is to ensure that accidents do not result in serious human injury. The approach considers that human limitations - what the human body can stand in terms of kinetic energy – is an important basis upon which to design the road transport system, and that other aspects of the road system, such as the development of the road environment and the vehicle, must be harmonised on the basis of these limitations. Road users, vehicles and the road network/environment are addressed in an integrated manner, through a wide range of interventions, with greater attention to speed management and vehicle and road design than in traditional approaches to road safety".

4.1. The Traditional Approach

Accident investigation plays an important role in the development of road designs. Traditionally, it begins with the consequences being assessed at each accident location, which is generally considered to be the final point where the car comes to a halt or where the collision or the damage occurs.

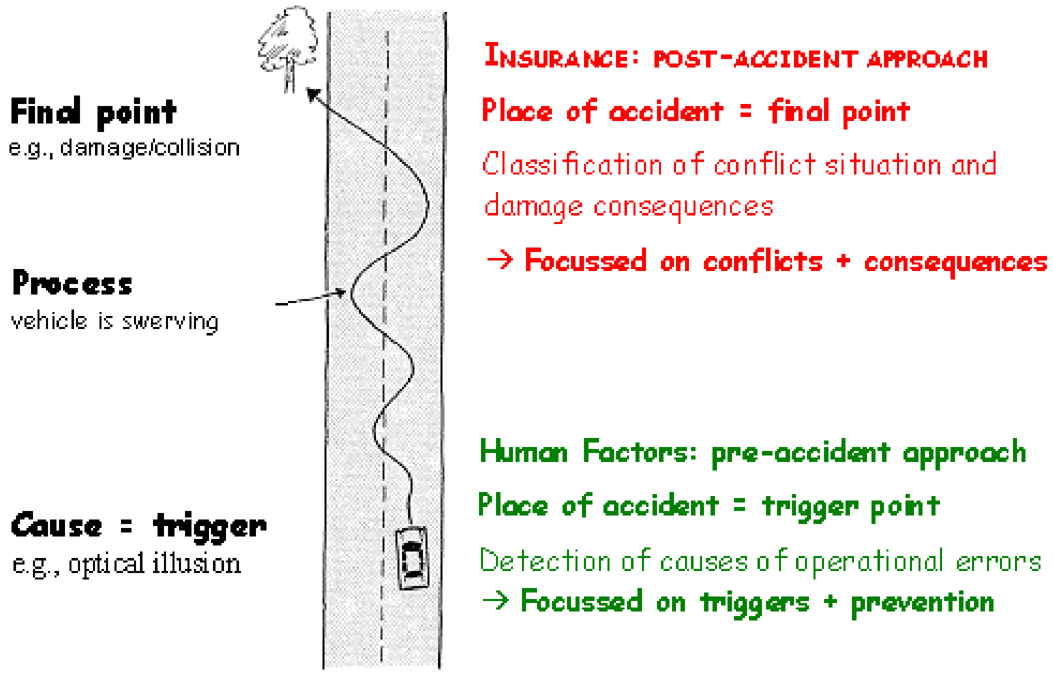
In this case, black-spot analysis commences with a review of police data to identify correlations between accident features and "suspicious" road features (e.g. grip, geometry, wheel rut) or "suspicious" driver features (e.g. performance deficits, drunkenness, abilities, age, sex). On the one hand, this method is convenient, but on the other it is fraught with difficulties. There has been a lack of specified inspection features and no validated procedures that take into consideration the background of driving errors. Sometimes it is obvious that the road should be reconstructed. But very often the analysis ends without reaching any conclusions as to what can be done. As a result, the recommendations try to minimise the consequences of the accident, for example through the installation of crash barriers, additional warning signs, speed limits or, very often, traffic signals.

Traditional passive safety measures lead to the achievement of "failure-forgiving roads". They often encompass advance warning of hazards for the driver in the form of road features (for instance, rumble stripes). But roads must also be designed in such a way that the road user is neither confused nor invited to take risks. Road designs also need to be underpinned with the concept of making the road "self-explanatory". The goal of the notion of "self-explanatory road design" is to ensure that interpretation of road features is consistent with the action that they are required to take.

4.2. The Human Factors Approach

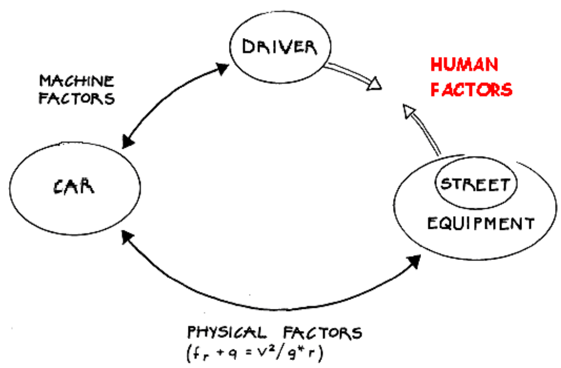
By contrast, the Human Factors concept takes into consideration the triggers of the driver's reactions and patterns of behaviour, which may result in an accident.

In applying the Human Factors concept to traffic accidents, the road safety expert seeks to establish the reasons that led to a driver's operational error, which finally resulted in an accident. This approach is not new to road design. In the 1930s, basic ideas from the Human Factors concept were taken into account in planning major roads and highways.



After decades of trial and error seeking to adapt road users to the technical elements of the transport system (vehicles and roads), it has now been established that the opposite is more effective: adapt the technical subsystems to road users' abilities and limitations.

It is well known that human factors have an enormous influence on the safe handling of technical systems. Human factors can be described as people's contributions to damaging events. It is the generic term for those psychological and physiological patterns which are verified as contributing to operational errors in machine and vehicle handling.



In the case of road safety, the human factors concept considers road features that influence driver behaviour.

Many of the often-observed operational errors result from the direct interaction between road characteristics and the driver's reaction characteristics. Because the driver's reaction characteristics cannot be changed, attention should be focused on a self-explanatory road design. The PIARC Guideline "Human Factors Guiding Principles: Spatial perception of driving environment for Safer Road Infrastructure" explains the relationship between several road features that trigger incorrect driving reactions, most of which happen unconsciously. Detailed examples and sketches allow the engineer to understand the relationship between bad road features and operational errors. They can be used as a kind of checklist in “on-the-spot” investigation of accident points or in road safety inspections (RSI). They can also be used to qualify planning and design processes in road safety audits (RSA).

Such as the physical factors of geometry, dynamics, braking distances etc three main classes of human factors have been detected:

1. The 6-Second Rule: The road should give the driver enough time

Average drivers need 4–6 seconds to completely change their driving programme. At a speed of 100 km/h this results in a distance of up to 300 m being travelled while the change is being made. A user-friendly road will allow an appropriate adjustment of driver behaviour to a new situation. It is necessary to arrange transition zones, remove visibility restrictions, make junctions perceptible or use markings to indicate at least 6 seconds before critical points such as junctions, curves, railway crossings, bus stops or bicycle paths.

2. The Field of View Rule: The road must offer a safe field of view

Motorised driving changes the field of view much more than any other movement. Monotonous or high-contrast periphery, optical misguidance and illusions affect the quality of driving. The field of view can either stabilise or destabilise drivers, and can tire or stimulate them. For example, a user-friendly, self-explanatory road avoids monotony, optical guiding lines not parallel to the road edge or optical guiding lines with gaps. It also avoids dominant eye-catching objects that distract the view axis away from the road axis.

3. The Logic Rule: The road has to follow driver’s perception logic

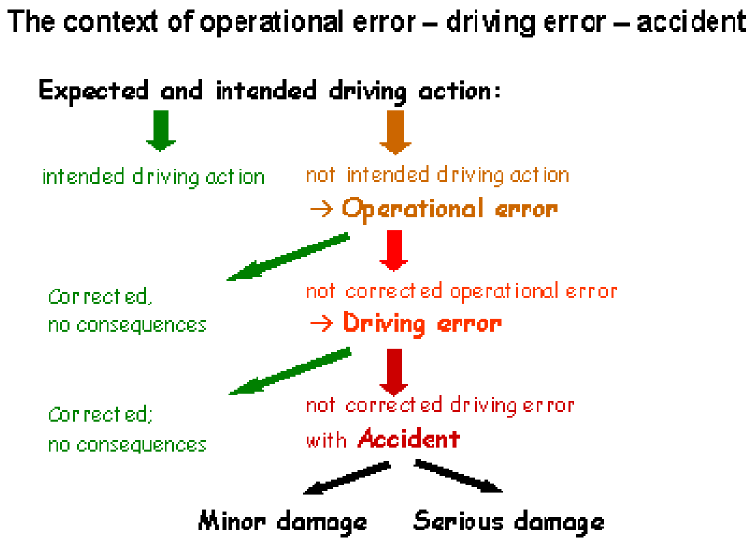
Drivers follow the road with an expectation and orientation logic formed by their experience and recent perceptions. Unexpected abnormalities disturb a mostly automated chain of actions, and may cause drivers to “stumble”. Several critical seconds pass before the disturbance can be processed. Therefore planners should try to keep road characteristics flowing in a logical sequence. They should introduce inevitable changes as early and clearly as possible, and exclude any sudden changes that would confuse the driver.

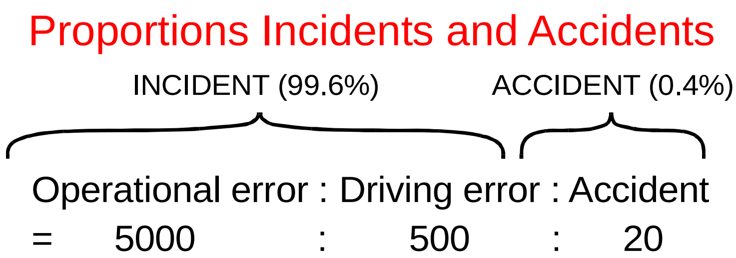
The human factors concept aims to reduce the probability of operational errors and ultimately of driving errors by promoting user-friendly and self-explanatory road design. This means that the road has to be designed for clarity, and that potentially dangerous points have to be designed so as to be understood, perceptible and recognisable. The road user should be neither confused nor invited to take risks. The goal of the notion of “self-explanatory road design” is to increase the unmistakable interpretation of road features. Such a user-friendly, self-explanatory road design should directly result in a reduction in accident frequency and severity.

Of course, the Human Factors concept cannot completely control the extent of accident damages as they are dependent on many other variables (the vehicle’s technical condition, weather, driver experience, car/road interaction, etc.).

An operational error, left uncorrected, can become a driving error. Often the driver is able to correct the driving error. If not, it could cause an accident. Generally, the driving error is the possible result of an operational error. The driver has brought the vehicle to an undesirable position. The driver may be able to correct this driving error by steering, speeding up or braking and the driving error could have no consequences. On the other hand, it could cause an accident.

Driving errors can be detected by skid marks on the road and on the shoulders; remains of mirrors/bumpers and other car pieces; damage, traces of paint or mud on safety barriers or other road equipment.





The first edition of the Human factors guideline was published in 2008. During the session 2007 – 2011 it was upgraded and translated by a working group comprising of engineers and psychologists to provide further guidance on engineering design considerations such as:

- Transition zones
- Optical density of the field of view
- Lateral fixation objects
- Town and village entrances
- Multiple critical points
- Deficiencies in Traffic control devices

The working group developed a checklist of questions about how well human factors are already integrated into road design standards. Design standards from Canada, Japan, Portugal, Germany, Czech Republic, Netherlands, Hungary, China, India, South Korea, Malaysia, France, Burkina Faso, Australia and Mexico were audited.

The session of the Technical Committee C.1 will provide a number of reports about the results. It will also outline examples of best practices and propose improvements and recommendations for designers.

5. DEFICIENCIES IN URBAN ROADS – THE PERSPECTIVE OF VULNERABLE ROAD USERS

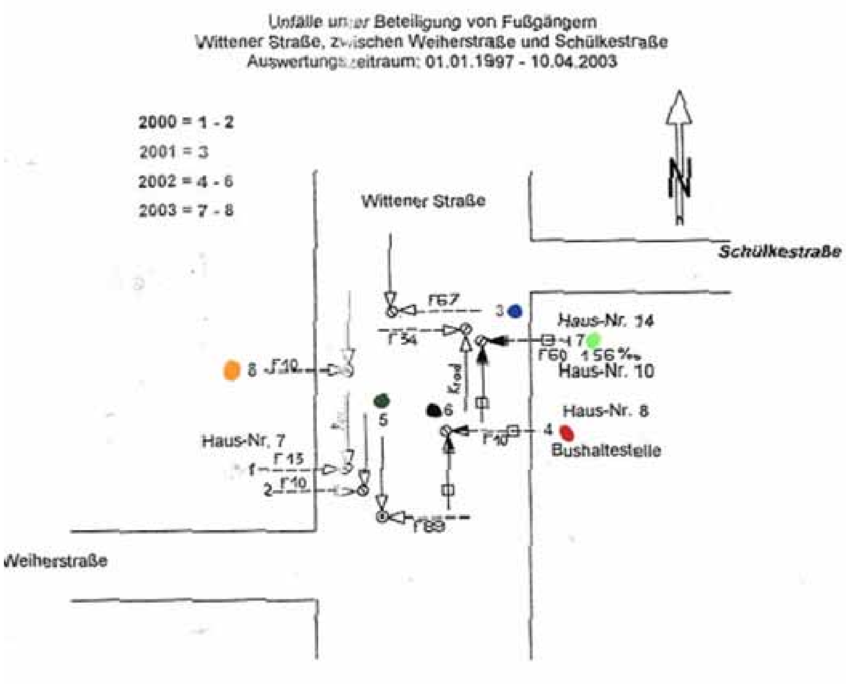
5.1. Introduction

While guidelines, processes and recommendations for designing motorways, highways and interurban roads are generally very well structured, organised and known all over the world, less guidance is available about design of urban roads. Given the increasing evidence of accident patterns on urban road networks, it is evident that urban road risk analysis could be improved. Most deficiencies in urban road environments relate to vulnerable road users (VRU). Sight distance (indivisibility) between vehicles and vulnerable road users is a very important consideration, especially with respect to parking layout designs to ensure adequate visibility between vehicles and pedestrians/bicyclists at intersections and pedestrian crossings. Visibility restrictions reduce the opportunity for drivers to perceive and react to conflict situations in sufficient time. While this issue is evident in all countries, the presence of sight obstructions on footpaths is more prevalent in developing countries. In Egypt, for example, issues such as mixed purpose roads traversing small villages and towns, dangerous urban road sections with uncoordinated or inconsistent alignment which result in high speed traffic in urban areas results in severe problems for vulnerable road users.

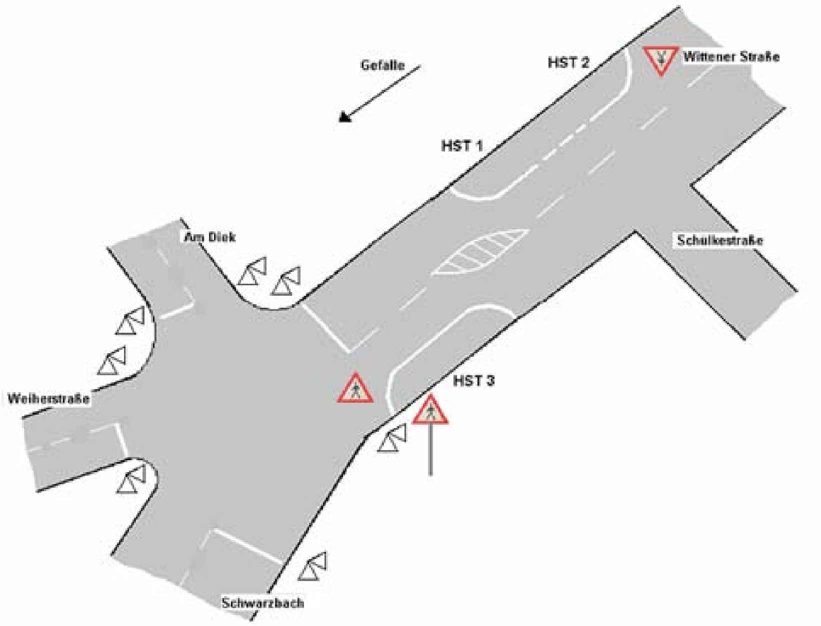
5.2. Reasons for Deficiencies from the Perspective of Vulnerable Road Users

Pedestrians, cyclists, and other vulnerable road users are over-represented in accident statistics in developing and emerging country statistics, even though motorisation in these countries is considerably lower. Children, the disabled and elderly are especially vulnerable: children cannot be expected to follow all rules and act sensibly and attentively all the time and have not development the judgement and skills to interact with traffic, while disabled and elderly people often cannot react as quickly and are not as mobile.

Figure 1 shows a typical example of a black spot in Wuppertal, Germany. On a 2-lane urban main road with a normal urban traffic situation (15000 vehicles/day, 50 km/h speed limit) eight severe accidents occurred over a three year period. The accident characteristics were the same on each occasion. – bus stops are provided on both sides of the road and pedestrians cross the road to access the bus. All of the pedestrians involved in accidents did not identify oncoming vehicles, and unfortunately were severely injured. Four of pedestrians were very young (under the age of 13) and two of them were elderly (over 67). This situation reflects the primary problem of urban roads: they are principally designed for car drivers and the cross section design is motivated principally by capacity, and very rarely, the requirements of VRUs. The accident commission in Wuppertal implemented low cost solution using warning signs and a refuge island, which reduced the complexity of crossing designs. Since this time, there have been no more accidents reported.



Accident diagram of a black spot at a bus stop in Wuppertal, Germany



Useful solution with a refuge island for a black spot in Wuppertal, Germany

Safety deficiencies are often one of the reasons that underpin the need for road improvements. Despite this, both preliminary and detailed designs frequently include safety deficits. There are many reasons to explain why this occurs, however the primary reason is often a result of the lack of coordination within the relevant authorities, and in particular, when there are multiple persons and institutions involved. For example, parking facilities could be provided in response to request from trades people and politicians, despite these facilities impacting upon intersection visibility. Another reason is that designs are often motivated by capacity and efficiency, rather than safety outcomes.

5.3. Typical Deficiencies in Urban Roads in Developed Countries

The detailed planning of a number of German urban main roads has been analysed. The results are considered to be typical for developed countries.

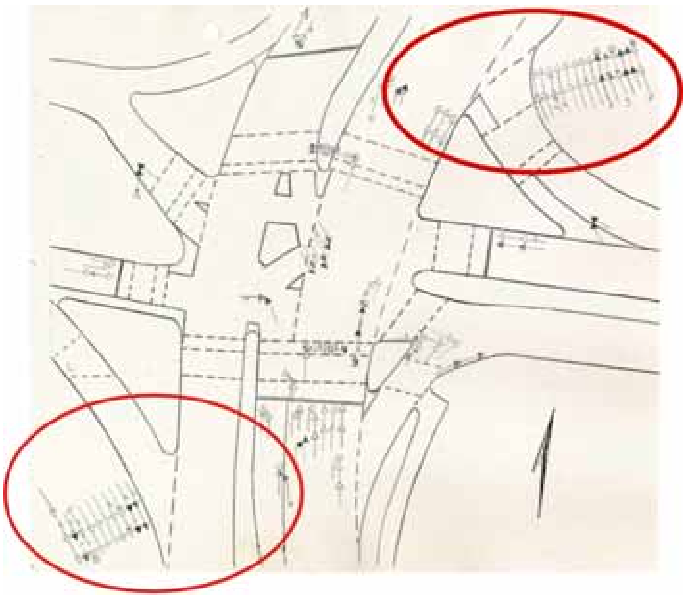
A number of typical deficits evident in the detailed planning are provided below. The examples are made up of singular deficits, despite the fact that there were often other significant deficiencies evident in the planning. These additional deficits are not illustrated.

One of the main deficiencies found in developed countries is the “Line-of-sight obstruction to bicyclist/pedestrians caused by parking cars”.

Example of visibility obstructions at pedestrian crossings caused by parked vehicles

Another significant deficiency is the “Lack of a barrier-free design”. The guiding principle “Design for All” is very important to fulfil the needs of vulnerable road users – many designs and existing situations fail to address the needs of children, elderly and disabled people, which could have been be avoided very easily.

An additional circumstance that needs to be considered is the frequent use of unsignalised slip lanes at intersection, despite these lanes often being characterised by clusters of rear-end collision accidents, which in some instances involve bicyclists and pedestrians crossing the road. This situation is shown in the following collision diagram (1-year). Despite this experience, slip lanes are a popular treatment to reduce delays at heavily trafficked junctions.



Accident diagram at segregated right turning lanes

Another deficiency in side road design is “adversarial line management” which leads to excessive speed. Wide straight roads without visual interruptions, such as curves or traffic calming devices, encourage higher speeds. It is important to make drivers aware of recommended speeds clear with the assistance of traffic calming elements.

Straight side road with excessive speed

5.4. Typical Deficiencies in Urban Roads in Developing Countries and Countries in Transition

A common deficiency in developing countries and countries in transition is the lack of access control along motorways and highways that traverse urban areas. Roads with different functions are not properly separated, resulting in roads performing both connection and access functions. The Cairo - Alexandria agricultural road in Egypt is one such example.

In other cases, existing roads through villages and towns are simply widened, often at the expense the pedestrian sidewalks for wide hard shoulders.

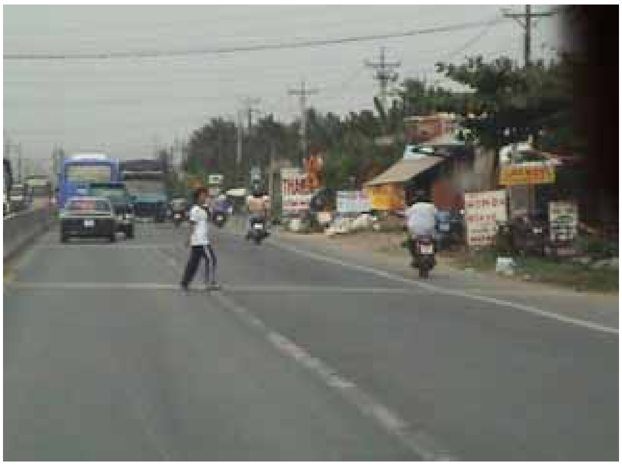
Romania National Road Nr.1 before and after demolishing the sidewalk

Road transport requires different design policies for urban and interurban roads (refer to PIARC catalogue on design safety deficiencies and countermeasures).

6. THE LINEAR SETTLEMENT DISASTER FOR VULNERABLE ROAD USERS ALONG INTERURBAN ROADS

6.1. Introduction

The most critical situation in respect of road safety is the mixture of functions where there is no clear distinction between the interurban and urban area. Here we find linear settlements often with commercial activities or roadside trading spreading along the interurban roads in an uncontrolled manner. Examination of crash data reveals a high proportion of pedestrian fatalities in these circumstances, which are the result of a lack of planning policy. This issue was discussed in two articles in Routes and Roads Nr 347. In Vietnam, they call them Coffin Roads – recently rehabilitated and widened national roads which provide business for local undertakers but overall, have an adverse impact on the country's economy.



Examples of linear settlements in Vietnam are visible on Google Earth

Linear settlements mostly result from a lack of access control and poor road network investment strategies and development planning. The result is an undesirable mix of residential and business uses spreading along heavily trafficked high speed arterial roads.

Development of this type impacts both safety and the efficiency of the road network function. Travel speeds are reduced and travel time increases, impacting on the movement of people and goods. In addition to the impacts on safety and efficiency, it also affects the health of people living along these roads, due to noise and pollution. The provision of infrastructure, such as water supply and sewerage, is less efficient.

6.2. The Counter Strategies

Land use planning should be considered as an integral task in most of the PIARC topics – financing roads, road safety, performance management and sustainable mobility.

Road network infrastructure that functions well is crucial for a country's economy. Road network improvement should be a key priority of development aid projects. Connectivity between major centres is essential for trade and exchange and should be separated from local road networks to ensure quality of life. The latter seems to be neglected in most aid projects in developing countries.

Separation of vulnerable road users from roads used by high speed traffic has to be of a principle underpinning national transport policy and an issue of cooperation for Ministries of Transport, Economy, Housing, Agriculture, Interior, Environment and Finance.

It is necessary to control the land use along interurban roads and to rigorously control direct property access from the main carriageway. While many countries have legislative provisions to manage access control, the effectiveness of the controls can be diminished by bribery and corruption. In many cases, the road administration has no power at all to control access. An international review of legislative provisions to manage access control and its enforcement should be an issue for consideration in the next session.

Access control is only the last part in the chain that commences with master land use planning for urban development and building development control. Road network planning supported by Road Safety Impact Assessments (RSIA) needs to be integrated with land use planning.

This new approach to infrastructure safety management will be further developed in the next PIARC session from 2012 to 2015.

Donors of aid for development should find ways of guaranteeing that their contributions have a sustainable effect on the countries' economies and safety so that the benefits are not eroded by the lack of controlled planning. However, financial sponsors need to realise that investment in interurban roads alone is not sufficient. Community networks for residential and industrial areas have to also be supported – aid packages need to be holistic.

An example of an alternative approach is evident in Germany. There is a special budget for any traffic development in the communities – for both public and private transport. The Ministry of Transport coordinates funding of both nationwide investment in railways and roads and local community transport projects.

6.3. Solutions for Deficiencies

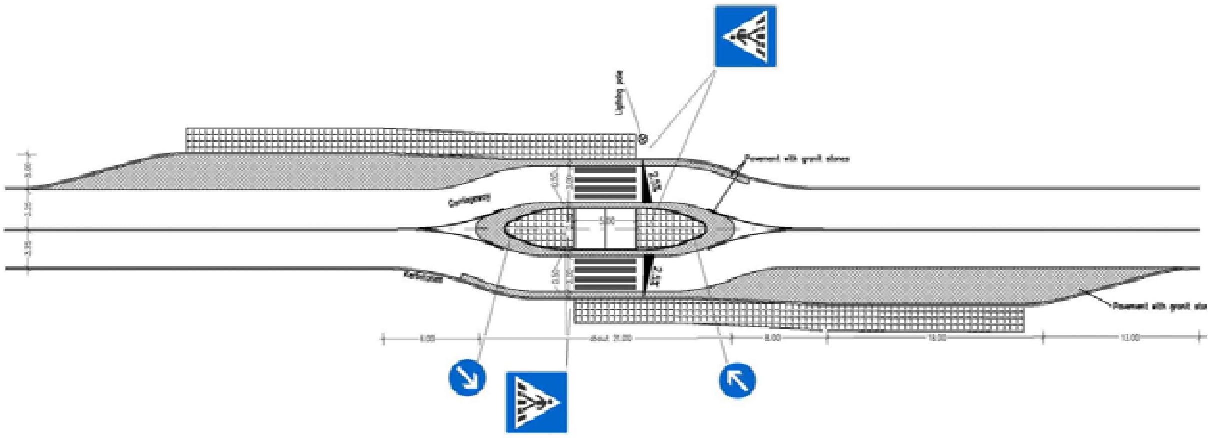
The answer to existing infrastructure safety problems for vulnerable road users within linear settlements is the separation of urban and interurban traffic streams and calming local road traffic using sustainable speed management practices.

Separate local distributor roads or agricultural ways running parallel to highways are the best solution for longitudinal separation of agriculture vehicles, bicyclists and pedestrians from motor vehicles.

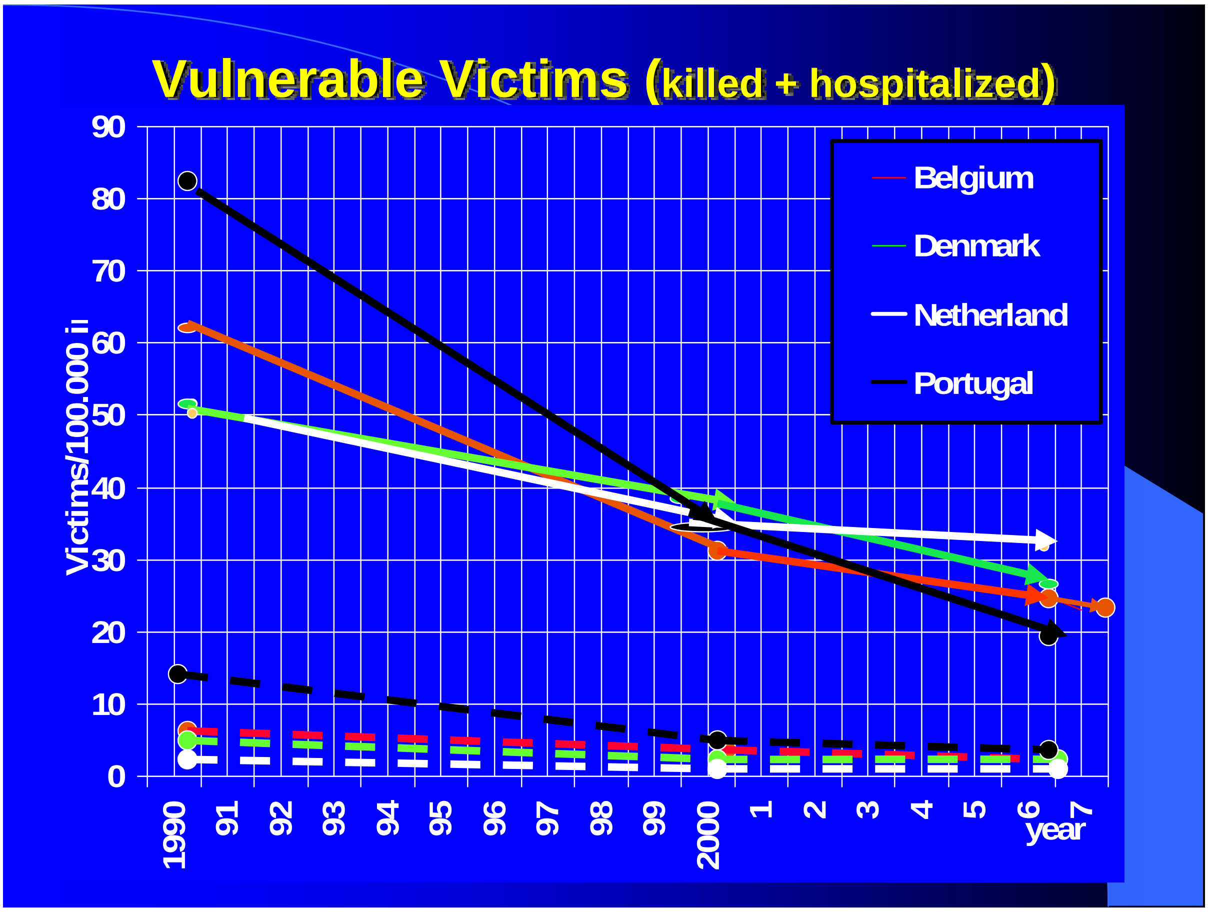
The cross section of the road should change where the built-up area begins. It is important that lane width is reduced. Road shoulders, which are appropriate outside built-up areas, should be discontinued and replaced with raised paved sidewalks separated by kerb where the built-up area begins. In most cases a narrower cross section is adequate.

International experience has shown that line marking and signing alone will not sufficiently regulate traffic speeds at such locations. In Egypt, local authorities construct humps at the entrances of the villages. Care is required to ensure that these treatments do not create a safety problem as a resulting of vehicles reducing speed suddenly and unexpectedly.

Supplementary visual cues and channelisation are required to alert motorists to the change in road environment so that they reduce speed prior to encountering situations such as pedestrian crossings, bus stops and intersections.



The PIARC catalogue of design safety countermeasures includes examples of traffic calming measures to address the needs of vulnerable road users. The following graph demonstrates the success of such measures in European countries.



The session of TC C.1 accords with the Global Plan for the Decade of Action for Road Safety 2011-2020 in several activities of pillar 2: Safer Roads and Mobility. Presentations outlining solutions for linear settlement safety issues in Syria, Togo, Bangladesh, India and Nigeria have been developed.

6.4. References

1. Twinning Project EG08/AA/TP13: The Twinning Expertise for Enhancing Road Safety in Egypt, Cairo 2011
2. Forschungsgesellschaft für Straßen- und Verkehrswesen: Guideline and standards for the design of urban roads, orig: Richtlinien für die Anlage von Stadtstraßen, Köln, 2006

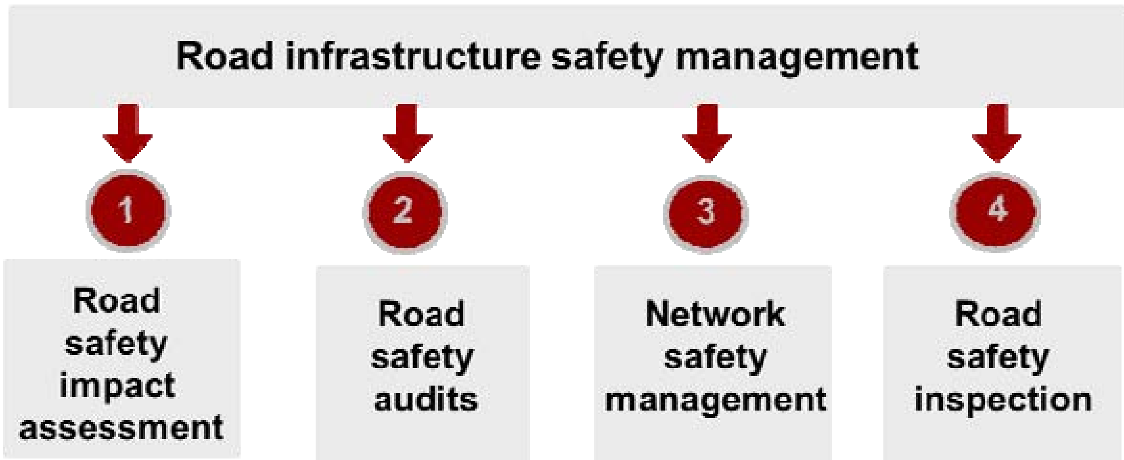
7. METHODS FOR ROAD SAFETY IMPACT ASSESSMENT (RSIA)

Road infrastructure is a contributing factor in many severe accidents – safer infrastructure planning has the potential to provide significant benefits. Road safety problems are often introduced in alignment planning and in master plans e.g. for road networks, urban development and for all kinds of land use. Strategic Environmental Assessments (SEA) and Environmental Impact Assessments (EIA) are already implemented in most countries' planning procedures. However, road safety still competes with other private and public interests and it is often assigned a lower priority.

To date, there have not been many methods and standards available for assessing the performance and forecasting the safety effects of plans and projects. However, the European Parliament published Directive 2008/96/EC which introduces a comprehensive system of road infrastructure safety management. The European member states implemented Road infrastructure Safety Management in their law late in 2010 and most operate within the requirements of the Directive. Similar instruments also exist in other countries, such as the United States.

Road infrastructure safety management should influence decisions to improve road infrastructure with the aim of increasing road safety for all road users. Road authorities are required to apply the provisions to the entire road network (national, regional and local roads), in recognition that while severe accidents happen on interurban and rural roads, most risks occur on urban roads.

Infrastructure safety management focuses on the following four procedures:
- Road safety impact assessment
- Road safety audits
- Network safety management
- Road safety inspections



While road safety audits and inspections are known worldwide since PIARC published the Audit and Inspection Guidelines and the Road Safety Manual, the instrument and the methods of a pro-active safety impact assessment are not so far established.

Road safety impact assessment require a strategic comparative analysis of the impact of a new road or a substantial modification to the existing network on the safety performance of the road network, at the initial planning stage before the infrastructure project is approved. The purpose is to demonstrate, on a strategic level, the implications on road safety of different planning options. The development of a methodology which allows a reliable forecast of accident rates for different solutions is not easy, but it is extremely important in low and middle income countries, where land use and urban development policies often lead to extremely unsafe road conditions and result in many vulnerable road user victims.

For this reason, road safety impact assessment has become a focus of the Global Plan for the Decade of Action for Road Safety 2011-2020, developed in several UN-Road Safety Collaboration meetings under the roof of the World Health Organisation. Activity 2, under pillar 2 for safer roads and mobility, is “Promoting the needs of all road users as part of sustainable urban planning, transport demand management and land-use management by including safety impact assessment as part of all planning and development decisions”.

Safety impact assessment are intended to be applied at the planning stage, preceding the development of a design for the scheme, analogous with environmental impact assessment.

Scenario analysis methods are used to carry out a safety impact assessment. The elements of the assessment include:

- Problem definition;
- Description of the current situation and the “do nothing” scenario;
- Formulation of road safety objectives;
- Analysis of impacts of the proposed alternatives;
- Comparison of the alternatives (including cost-benefit analysis); and
- Identification of the best solution.

The starting point is the existing road network, the current pattern of traffic on that network, and the safety performance of the network. This information relates to a road network which is made up of roads of a number of types that have different road safety characteristics. Each road consists of junctions and stretches of road between the junctions, with associated traffic volumes, and numbers of accidents and casualties. Alternative scenarios to this current situation are the possible changes being studied in respect of the physical infrastructure and the associated traffic volumes in the road network in the future. If, for example, a new road is to be added to the existing network, the traffic and transport models can be used to estimate what this will mean for the traffic volumes throughout the network in the future.

The central step is to interpret these changes in terms of the impacts they will have on the numbers of accidents and casualties. To accomplish this, quantitative indicators of risk (such as casualty rates per million vehicle-km) are required for each type of road, supplemented if possible by corresponding indicators for each type of junction. One way of obtaining such indicators is to estimate them at a national level and adjust them if necessary using data for the area in question. In addition, the design details like the cross section, the alignment, the road side features and all other elements which influence the performance of safety should be evaluated and taken into consideration. This information enables safety impacts to be estimated. In addition, a cost-benefit analysis could be used as a monetary valuation of safety (and other) impacts which are related to the costs of the measures.

At the very least, safety impact assessment should lead to safety impacts being minimalised where road functions, road schemes or measures are changed.

So far only a few road safety impact assessment tools and models have been developed or are still the subject of study. These tools are not yet widely used. A comparison of different models and tools regarding applicability, quality and availability of data regarding possible indicators will be worked out in the group in order to support a better understanding of underlying traffic and transport patterns which influence road safety.

In a similar manner to the development of guidelines for road safety audits and inspections, PIARC has again taken the initiative to create a guideline for Infrastructure Safety Management. This session of Technical Committee C.1 will outline RSIA practices adopted in some countries, as a precursor to the development of a PIARC Guideline in the new Strategic Plan 2012-2015.

8. WORK ZONE SAFETY – A GROWING ISSUE FOR EMERGING COUNTRIES

8.1. Introduction

Many road safety engineers and planners are familiar with the 4 (sometimes 5) E's for safety 'Engineering', 'Evaluation', 'Education' and Enforcement' and, sometimes, 'Emergency services'.

For the safe, efficient and effective management of temporary traffic management (TTM), it is proposed that a 4 C's principle be adopted i.e. TTM should be designed, operated and maintained such that the works are: Clear, Concise, Comprehensive, and Credible.

Guidelines developed by this working group encompass:

1. Introduction (including the results of the International Survey)
2. Principles: This chapter addresses "what we should think about" in work zone design, implementation and operations. It is general in nature.
3. Definitions: This chapter covers language conventions used in the guide
4. Roles and Responsibilities: This chapter takes a broad view, as the roles and responsibilities of parties differ in every country. However, this provides a structure for understanding how the important players can work together.
5. Planning and Design: This technical chapter includes information on achieving a balance between safety and mobility throughout the work zone planning and design process
6. Implementation and Operations: This technical chapter includes detailed information on signs and traffic management techniques for setting up and operating work zones.
7. Personnel: This chapter provides an overview of appropriate training and equipment for workers. Given the wide range of occupational health rules and regulations, it is very general in nature.
8. Typical Layouts: This technical chapter provides specific examples of methods of designing and operating a variety of work zones types on a variety of road types.

9. Checklists: This chapter provides straightforward information to use in determining if the safety issues for your work zone have been appropriately considered.

The focus is on safety of both workers and road users in construction zones. The guideline document emphasizes low-cost solutions that can be implemented in developed and developing countries.

8.2. Statement of Issues

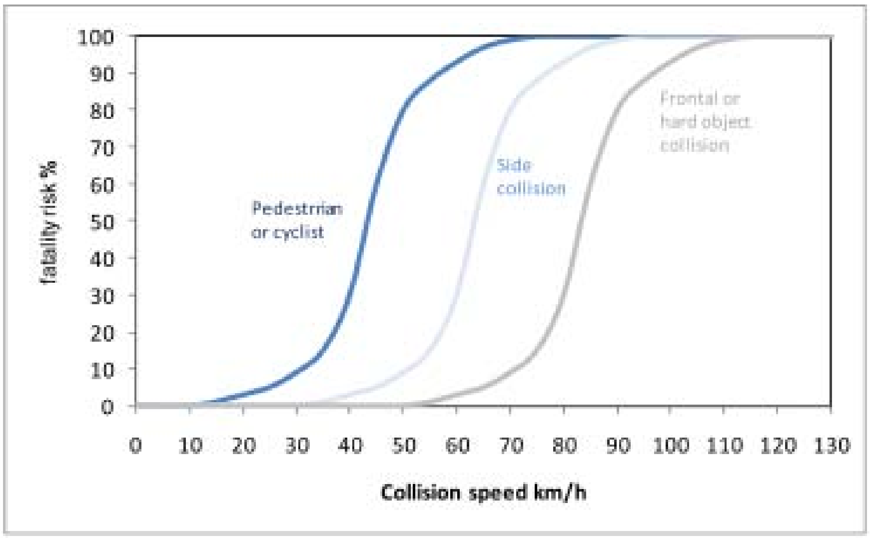
Traffic fatalities are an international health concern. The World Health Organization[1] estimates that road traffic crashes kill 1.2 million people annually and injure or disable between 20 and 50 million. Outside of the tragic human costs, the economic burden of these preventable deaths and injuries is staggering – US$518 billion. The fatality rate per population is significantly higher in low and middle-income countries than in high income countries.

Adequate transportation is a requirement for all economies, but particularly for developing and transitional economies. Improving and expanding the roadway network is critical to quality of life as well as economic success. There is very little reliable international data on how fatalities in work zones contribute to the overall roadway fatality problem. According to *Advanced Research on Road Work Zone Safety Standards in Europe (ARROWS)*[2] "It seems rather well substantiated that work zones are relatively unsafe places to be. However, the estimates regarding how large the relative increase in the accident risk is in a work zone vary from a few to a several hundred percent. The sources of these enormous differences are unclear….However, one would suspect that the former number (of a few percent) is more likely than the latter." United States figures[3] indicate that work zone fatalities make up about 2% of the overall fatalities, and of that figure, most of the fatalities are drivers travelling through the work zone (approximately 80%). In Austria in 2008, work zone fatalities on motorways represented 2.5% of all fatalities and none of these were workers. In the Netherlands, traffic crash statistics show an annual average of about 20 fatalities in work zones, with less than one (on average) worker fatality. Even if the number of crashes and injuries occurring at work zones is still relatively small in relation to crashes on the open road, improving work zone safety is a crucial part of a wider plan to reduce the death toll on our world's highways. Further, anything we can do to prevent even a single work zone fatality, given not only the financial costs, but the cost of a human life to society, is worthwhile and necessary.

The number of work zones is increasing – in developed countries to replace aging infrastructure and in developing and transitional countries as their network matures. With an increase in traffic volumes, the demands to improve the networks and provide additional capacity increases. Further, the positive effects of countermeasures to improve the safety of road works is proven – Austria instituted a work zone safety program on motorways in 2004 that has led to a reduction of more than 60% in the number of injury crashes.[4] Now the risk of an injury accident in a work zone is the same as on the rest of the network. The UK reports[5] similar findings for minor works on trunk roads and motorways: "there was not a statistically significant increase in accidents due to the works".

For road workers, the safety issues of the work zone are obvious – their workplace is surrounded by many rapidly moving vehicles. For the driver travelling in a work zone, the hazards, although less noticeable, are still important. In the frequently changing environment that occurs during road work, the driver is often surprised and may not have the necessary information or space to make safe and sound decisions or manoeuvres.

The basic strategy of a Safe System approach in a work zone is to ensure that in the event of a crash, the impact energies remain below the threshold likely to produce either death or serious injury. This threshold will vary from crash scenario to crash scenario, depending upon the level of protection offered to the road users involved. For example, the chances of survival for an unprotected pedestrian hit by a vehicle diminish rapidly at speeds greater than 30km/h, whereas for a properly restrained motor vehicle occupant the critical impact speed is 50km/h (for side impact crashes) and 70 km/h (for head-on crashes).



Collision speed – fatality relationship (Wramborg, 2005)[6]

Clearly, complete separation of drivers from the work area is the most comprehensive approach to improving work zone safety, and full road closures are used in some circumstances. However, maintaining mobility while ensuring safety is the balance that most agencies face when designing and implementing a work zone. Certain principles, such as minimizing the duration of work, actively communicating information to road users, and positively separating the workers from the traffic are commonly used to strike this critical balance.

Given the need to build, improve and maintain roads while they are open to traffic, the vulnerabilities of the road worker must be considered. The risks to workers from the travelling public, as well as the risks to the travelling public because of the work zone, can be minimized. However, protecting the driving public, as well as these vulnerable road workers, requires cooperation and collaboration from many sectors. At a minimum:

- Politicians must take an active interest in road safety;
- Highway and road authorities must develop and implement safety standards for road works;
- Designers must consider safety issues as they develop roadway plans;
- Contractors must assure their personnel are appropriately trained and equipped;
- Road workers must actively follow safety procedures;
- Drivers must behave responsibly;
- Police must actively participate in speed management and work zone safety.

8.3. Results of an International Survey on Improvements in Safe Working on Roads

In July 2008, the World Road Association (WRA) team addressing work zone safety under Technical Committee C.1.4 *Safer Road Infrastructure* prepared and distributed a survey to all committee members. The survey covered the following topics:

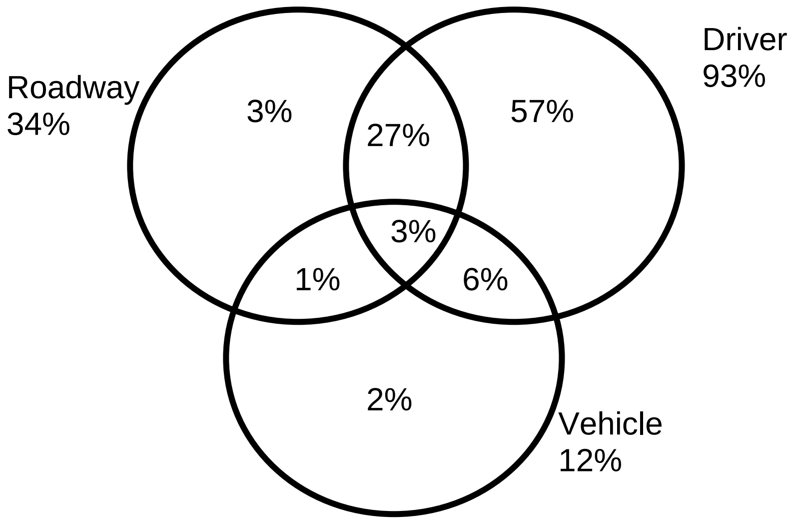
- Guidelines and Standards
- Legal Aspects
- Surveillance of the Work Zone
- Training and Accreditation of Workers
- Communication
- Urgent Interventions
- Crash Statistics in Work Zones

The majority of respondents identify driver related issues (inattention, speeding) as current work zone problems. Almost half the respondents mentioned an issue related to standards, either they were insufficient, or not being followed properly. Less frequently mentioned problems included: the overall crash problem and short duration work zones.

Roadwork areas and other road traffic incidents cause additional costs and other inconveniences to road users and society in general. (photo courtesy J. Klang)

8.4. Road Safety – Human Factors Basics

The highway system consists of three major elements: the driver, the roadway and the vehicle. Environmental factors, including weather issues, can be overlaid on these three major elements. As shown in the next figure, the overwhelming majority of crashes include driver factors. US data shows over half of the causative factors attributed strictly to the driver and over a quarter attributed to driver-roadway interactions. Finnish data[7] provide a different picture, with about 11% of crashes attributed only to the driver, and almost 60% attributed to a combination of driver, roadway and vehicle interactions.



Causes of crashes in the United States[8]

Regardless of the details, it is clear that the driver element must be appropriately considered in the design, operations and control decisions made by traffic engineers.

Vehicle and highways have improved over the year with the advent of crumple zones, air bags and seat belts and the implementation of better pavements, improved traffic control device materials, and safer roadway and roadside designs. The driver, however, has not changed dramatically since the advent of the automobile, and we do not anticipate any significant improvements in the basic skills that are needed to operate a motor vehicle. To continue to improve the safety of our highways, we must design and develop a system that meets the needs of the weakest element in the system and the one least amenable to change: the driver.

Human factors focus on designing systems that meet user needs. By better understanding the human component, we can make choices about the roadway component that insure that our design decisions are not contrary to drivers' needs and capabilities. The system model presented above seems simple enough – there are only three components, but of course, the reality is far more complicated. "Accommodating the driver" is not a simple task, but because incorporating driver needs in highway design has such great potential to improve the safety and efficiency of our roadways; we must include human factors information in our traffic engineering processes.

The driving process can be divided into three basic phases: Drivers need to gather and process information, make decisions, and execute actions. Roadway elements, particularly in complex situations like work zones, significantly affect how efficiently drivers perform these actions and therefore how safely they operate.

8.5. Drivers Actions and Engineering Elements in Work Zones

Linking driver needs to design and engineering decisions allows us to adequately consider the driver needs in laying out a work zone. Characteristics of roadway elements can be manipulated in to make them better affect drivers' abilities to safety perform those actions. The principals of insuring that works are clear, concise, comprehensive and credible apply here.

In order to minimise risks to drivers and workers and improve safety, engineers must consider the safety implications of every decision. For instance, if you design a six-lane facility, how will you provide appropriate signing to maintain safe operations for a lane closure during later repaving operations? If you decide to minimise the size of the hard shoulder, how will guardrail repair personnel maintain an adequate distance from the travel lane? Is the need for later road works taken into consideration when pavement life-cycle is addressed? Has the need for maintenance on bridges and in tunnels been considered in their cross section design? Safety issues must be considered not only for the immediate work zone you might be creating today, but for the roadway you are leaving for tomorrow for others to work on. Just as lifecycle costs are considered in a pavement decision, so the safety implications throughout the lifecycle of a roadway.

8.6. References

1. *World Report on Roads Traffic Injury Prevention*. World Health Organization (2004)
2. *ARROWS* A Transport RTD Project financially supported by the European Commission under the 4th Framework Programme
3. Fatal Analysis Reporting System, US Department of Transportation, National Highway Traffic Safety Administration
4. ASFINAG, Annual Report on Road Safety 2008
5. *Safety Performance of Minor Road Works on Trunk Roads and Motorways*, Published project report PPR 190, TRL Limited, G. A. Coe, M. E. D. Gillan, J. C. Mitchell, P. Turner, and J. Weekley (December 2006)
6. Towards zero: Ambitious road safety targets and the safe system approach – Transport Research Centre of the OECD and The International Transport Forum, ISBN 978-92-821-0195-7 © OECD/ITF, 2008
7. In-depth Investigation of Fatal Road Accidents in Finland 2009, Finnish Motor Insurers' Centre, Traffic Safety Committee of Insurance Companies (VALT)
8. Interactive Highway Safety Design Model: Accident Predictive Module. *Public Roads*, Winter 1995