ROAD SAFETY MANUAL
A GUIDE FOR PRACTITIONERS!

PLANNING, DESIGN & OPERATION

INFRASTRUCTURE MANAGEMENT

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World Road Association (PIARC)

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9. INFRASTRUCTURE SAFETY MANAGEMENT: POLICIES, STANDARDS, GUIDELINES AND TOOLS

KEY MESSAGES

- Improvements to infrastructure can contribute substantially to reductions in death and serious injury. Many high severity crash types can be eliminated with the effective use of infrastructure. This includes crashes that are thought to be caused by human error and non-compliance.
- Few infrastructure investments produce such high benefits as infrastructure measures targeted at making road safety improvement.
- Road infrastructure is often the single most significant factor that contributes to the severity outcome of a crash.
- Clear and defined policies relating to the delivery of Safe System infrastructure are required to drive road safety improvements.
- Good examples of infrastructure policy can be found. Benchmarking against good practice should be undertaken to identify required changes in policy. Care should be taken when borrowing policy from other countries to ensure that it is fit for local conditions. However, there are a number of universal approaches that are applicable.
- Standards, guidelines and tools are a mechanism to translate policy into action. Without linking to policy, such documents and tools can be reactive and delivery of safe infrastructure can lack structure and direction.
- Guidelines to assist in the implementation of infrastructure policy exist. These can be used to assist in the delivery of Safe System infrastructure, although they will need to be adapted for local conditions. Such guidelines require constant review and update based on good practice.
- The occurrence of key crash types on high risk routes can be reduced through effective infrastructure treatments. For those just starting to address safety, corridor demonstration projects are a very effective way to improve safety.
- A number of tools are available to help implement safe infrastructure. An overview of tools is provided in this chapter, while details can be found in Assessing Potential Risks And Identifying Issues and Monitoring and Evaluation of Road Safety.
9.1 INTRODUCTION

The Road Safety Management System provided information on the broader management of road safety, while Road Safety Targets, Investment Strategies Plans and Projects highlighted the need for effective road safety targets, policies and plans at the national and jurisdictional level. This chapter moves the focus to the importance of policies, standards, guidelines and tools relating to road safety infrastructure. The planning, design, operation and use of the road network will only produce effective results when interventions (including safe infrastructure programmes and projects) are implemented as part of an effective management system. An evidence-based approach is required that links institutional management functions to interventions, which in turn produce desired results. Details of this road safety management process are provided in The Road Safety Management System.

Information is provided on the development of policies, standards and guidelines, as well as tools to assist in delivering safe infrastructure. The introduction provides general principles of infrastructure safety management, drawing on material presented in earlier chapters (see especially The Road Safety Management System and Road Safety Targets, Investment Strategies Plans and Projects). It also sets a framework for later chapters by providing the overall approach to the assessment and treatment of road infrastructure for effective road safety outcomes. This approach involves the assessment of risk (identifying high risk locations discussed in detail in Assessing Potential Risks And Identifying Issues), identifying the issues contributing to these crashes (also in Assessing Potential Risks And Identifying Issues) identifying and selecting appropriate solutions (Intervention Selection And Prioritisation), prioritising action (also in Intervention Selection And Prioritisation) and monitoring and evaluation (Monitoring and Evaluation of Road Safety). This overall process is graphically represented in Figure 9.1:

![Figure 9.1 The infrastructure risk assessment process](image-url)
HOW DO I GET STARTED?

Start by assessing what infrastructure safety policies you have, and tools you already use, and assess whether these are the best for your situation. The information in this chapter will help identify required policies.

Train key staff to understand infrastructure safety management, and especially the principles provided under the Safe System approach ([The Safe System Approach](#)).

Collect and analyse crash data, as well as other intermediate data, starting with high risk routes ([see Effective Management And Use Of Safety Data](#)).

Start to develop tools to assess risks, initially through corridor and area demonstration projects utilising existing crash data as well as analysis of road deficiencies ([see Management Tools](#)).

Knowledge on effective interventions is required. Information on this issue is available in this manual ([Intervention Selection And Prioritisation](#)).

Staff need to be trained in the use of road safety infrastructure management tools.
9.2 GENERAL PRINCIPLES OF INFRASTRUCTURE SAFETY MANAGEMENT

In general, it is believed that driver error causes a large proportion of road crashes, with some studies suggesting that human error has played a role in over 90% of crashes (e.g. Sabey, 1980; Treat, 1980). Although the role of human error in road crashes is substantial, such figures downplay the significant role that infrastructure can have in achieving Safe System outcomes (also see the discussion on this issue in The Safe System Approach).

When a crash occurs, road infrastructure has the most significant influence on the severity outcome of a crash. Improvements to infrastructure can contribute substantially to reductions in death and serious injury.

Findings from Sweden identified that road-based factors were most strongly linked to a fatal crash outcome. Stigson et al. (2008) reviewed fatal crashes based on in-depth crash investigation, with crashes categorised based on factors that contributed to the crash outcome (as opposed to crash causation). The study identified that there were strong interactions between the three system components (vehicles, road infrastructure and road user issues), but that road-based factors were most strongly linked to a fatal crash outcome.

Further evidence of the role infrastructure plays in fatal and serious injury crash outcomes can be found from research that investigates the benefits of infrastructure safety treatments. Various studies have identified that well-designed infrastructure (such as roundabouts and protective barrier systems) can reduce fatal and serious injury crash outcomes by up to 80%. This reduction can occur regardless of whether crashes were the result of human error (also see Design for Road User Characteristics and Compliance). For further information on effective treatments, see Intervention Selection And Prioritisation.

There is a strong economic argument for the provision of safe infrastructure. Examples exist from many countries that demonstrate the benefits from targeted road safety improvements. OECD (2008) identified that such targeted improvements can deliver up to 60 times the benefit compared to the cost (i.e. for every $1 spent, benefits of up to $60 in terms of crash cost savings can be achieved). As identified by the UNRSC (2010), few other infrastructure investments produce the economic benefits of infrastructure targeted at improving road safety. Even more substantial investment programmes are able to return substantial safety benefits when compared to their costs. An analysis undertaken by iRAP (www.irap.org) on improvements to road infrastructure on the worst 10% of roads (i.e. those roads with greatest number of death and serious injury) in each country identified substantial potential gains when comparing the costs with the benefits. The average over all countries was a benefit-cost ratio (BCR) of 8:1 (i.e. $8 worth of benefits for each $1 invested). This ranges from a BCR of 5:1 in high-income countries, to 19:1 in upper middle income countries over a 20 year period.

A solid understanding of key infrastructure principles is required by road agencies and others responsible for delivering road safety. Some of the key elements of relevance to the development of infrastructure policy, standards, guidelines and tools include:

- Understanding of, and adherence to, the Safe System approach, including acknowledgement that designers are ultimately responsible for the design, operation and use of the road system, and therefore
the entire safety of that system (UNRSC, 2010).

- Safety needs to be embedded in planning and design. In order to have maximum and cost effective impact, safety needs to be included as early as possible. This includes ensuring that new projects have safety embedded and that existing roads are upgraded to account for Safe System principles.
- Priority policy issues for major roads include the need for a clear distinction and separation between inter-urban high-speed roads and urban roads (i.e. hierarchy); strong control and management of land use and urban development; and planning cities and communities for those without cars (i.e. walking, cycling and public transport). (UNRSC, 2010).
- There is a need to identify high risk locations through the traditional approach involving analysis of crash locations, and a proactive approach based on design elements and road and roadside features. Combining these approaches will maximise opportunities to identify risk. The focus when identifying high risk locations should be primarily on fatal and serious injury.
- Risk locations should be addressed in a cost-effective manner. Again, the focus should be on the elimination of fatal and serious injury.
- There is a requirement for monitoring and evaluation of the network, including safety performance and the impact of changes that are made. This assessment of change is often overlooked, but is required to ensure expected outcomes are met.

Guidance on the risk assessment process has been developed across many different industries and activities, including road safety. The process (briefly introduced in Figure 1) involves the identification of high risk locations; analysing data to determine the cause of this risk; identifying evidence-based solutions that are effective in addressing the risk; implementing these solutions; and then monitoring and evaluating the outcome. Each of these stages is explained in detail in Assessing Potential Risks And Identifying Issues to Monitoring and Evaluation of Road Safety.

In broad risk assessment terms, the chance of sustaining death or serious injury can be decreased by reducing the:

- exposure to the risk (an example may be to divert traffic from low quality roads to higher quality ones);
- likelihood of the crash (this includes the provision of a predictable road environment);
- severity of the crash (for example, by providing a forgiving roadside to reduce harm if a vehicle does leave the road).

With an understanding of these factors, crashes can be influenced in a number of ways through changes in the road environment. As examples, improvement in safety can be gained from:

- reducing exposure;
- regulating/controlling movements and turns, especially at intersections and access points;
- reducing speeds;
- reducing conflict points;
- separating vehicles of different mass (e.g. specific facilities for pedestrians and cyclists) and travelling in different directions (e.g. median barriers);
- warning road users of unusual or risky features (e.g. providing advanced warning);
- providing adequate information to enable road users to negotiate the roadway safely;
- removing hazards (e.g. utility poles and trees from the roadside);
- protecting road users from hazards that cannot be removed (e.g. providing guardrail and median barriers);
- improving surface friction.

Engineering-based treatments generally work by influencing one or more of these factors. Examples of such treatments and their effectiveness can be found in Project-level and Network-level Approaches.
THE ROLE OF POLICIES, STANDARDS, GUIDELINES AND TOOLS

Standards, guidelines and tools are the mechanisms that support the consistent interpretation and delivery of policies. Policies set the framework for road safety activity, and without these, delivery of road safety is reactive and lacks structure. Guidance on strategy and policy development can be found in Road Safety Targets, Investment Strategies Plans and Projects and in Development of Policies, Standards and Guidelines in Policies, Standards and Guidelines.

Changing established practice is often difficult, and careful management of this process is required. Strong leadership is needed to facilitate policy shift, and this needs to happen in parallel with an update of standards and guidelines.

Once policies are set, there is need for linkage to standards and guidelines. Standards (as well as road rules and regulations) dictate those things that must be done and typically have a legal basis. Guidelines and manuals provide direction on how things should be done. In contrast to standards, there is scope to deviate from the advice provided in manuals and guidelines, but this must be justified and assessed for the impact on safety outcomes. Standards and guidelines are typically based on many years of experience and outcomes from research.

It is important to note that compliance with standards and guidelines does not mean that safety will be maximised, and there are many examples where new roads have been built to standard but have a poor safety outcome. Standards and guidelines are often dated, and may not include adequate content based on Safe System principles. Standards and guidelines generally offer the minimum acceptable criteria for design. Departing from the minimum requirements is usually at a financial cost that is higher than providing the minimum standard.
There is much to be gained by looking to other countries for guidance on setting new standards and guidelines, and such an approach is important for benchmarking (also see Country Management System Framework in Management System Framework and Tools). However, often guidelines are directly copied from other countries without due consideration of local conditions, particularly adequate design for vulnerable road users, different vehicle types and road user compliance.

Also, guidelines often provide fewer options for use in constrained environments. It is typical that several compromises need to be made in road design. When combined, these issues can lead to poor safety outcomes (also see the discussion in Global Level in Policies, Standards and Guidelines on minimum criteria, and the concept of extended design domain). Typically, an assessment of the likely road safety impact is required to ensure that safety objectives are met. It is for this reason that approaches such as road safety audit (see Road Safety Audit in Proactive Identification) are required, and that when undertaken, these are not just a check against standards and guidelines.

Knowledge of the safety implications of design decisions is constantly improving, and with this there is sometimes a need to update policies and procedures. This includes the need to update standards, guidelines and tools.

Box 9.1 indicates how a policy decision that was initially driven by economic reasons at the political level has resulted in safer road design principles on major roads in New Zealand.

### BOX 9.1: NEW ZEALAND REVIEW OF DESIGN STANDARDS FOR ROADS OF NATIONAL SIGNIFICANCE

New Zealand has recently implemented a policy to improve the safety standard on Roads of National Significance (RoNS). The initial motivation for this policy was as part of an economic stimulus package, and investment through this programme was focused on the movement of freight and people more efficiently and safely, particularly around the main population centres. Currently, there are seven RoNS, each of which are key state highway links. As part of the national safety strategy, each of the RoNS will need to attain at least a four-star safety rating under KiwiRAP (the New Zealand risk assessment programme; NZ Ministry of Transport, 2013). A review of design standards was undertaken to ensure that this safety rating is reached. Key design elements to change to ensure this safety outcome are: the use of centre-of-road wire rope barrier, and roadside barrier systems. These treatments are aimed at targeting run-off-road and head-on crashes, two of the key severe crash types on New Zealand roads.
LINKAGE WITH OTHER POLICIES, STANDARDS AND GUIDELINES

Delivery of road safety infrastructure does not occur in isolation, and it is important to consider broader safety, road management and societal issues when developing policies, standards and guidelines. Similarly, it is important to advocate for road safety outcomes when developing broader transport and related policies. The case study in Box 9.2 provides a useful demonstration of linking infrastructure improvements to other safety improvements. Land use measures have a strong linkage to safety outcomes, an issue that is often overlooked in LMICs. Such measures define the type and intensity of the generated traffic, and the way it enters and exits the roadway. A detailed discussion on this issue can be found in Impacts of a Safe System Adoption on roles and Responsibilities of Authorities.
BOX 9.2: CASE STUDY – BELIZE MULTI-SECTOR ROAD SAFETY PROJECTS

The problem: Although Belize is only a small country; it recorded 70 road traffic deaths in 2009, equivalent to 21 traffic deaths per 100,000 population.

The solution: In order to address this issue, two projects were initiated. The first involved a review of safety management capacity (see Building Road Safety Management Capacity) and work to reach consensus on a multi-sectoral investment strategy for improving road safety management capacity. The second involved a Road Assessment Programme to evaluate the safety of 370 miles (almost 600 km) of road corridors. Both tasks were completed in January 2012, and identified several key issues and constraints affecting road safety in Belize. The results and findings were presented at a two-day workshop with a cross-section of public and private sector stakeholders. Over the duration of the workshop broad agreement was reached on the priority investments for inclusion in a road safety project. In accordance with World Bank capacity review guidance, it was recommended arrangements be made to test the effectiveness of the approach; illustrate the efficacy of the investments; and to generate wider stakeholder support and demand. Accordingly, a demonstration corridor was selected by the stakeholders to illustrate the impact of improved infrastructure; foster cooperation among stakeholders; and integrate the enforcement, post-crash care and educational initiatives.

In May 2012, the Caribbean Development Bank approved a loan to Belize for a Road Safety Project, with further funding provided by the government of Belize. This funding was for a project on a demonstration corridor, and aimed at reducing fatal and serious injuries. The multi-sector project focused on five objectives:

- improved safety of road infrastructure along the demonstration corridor;
- improved road user awareness of safety;
- improved driver behaviour and adherence to traffic laws;
- improved post-crash care;
- improved capacity to manage road safety.

In order to meet these objectives, the following project components have been undertaken:

- Road safety infrastructure improvements along an 80 km demonstration corridor of the Western Highway, between Belize City and Belmopan (also see Box 1 in Assessing Potential Risks And Identifying Issues).
- Road user education and awareness to support increased road user awareness and improve behaviours. The sub-components are public awareness and curriculum development for schools:
  - Road safety enforcement to support the improvement of traffic law enforcement on the demonstration corridor and in the municipalities of Belize City and Belmopan. This will occur through the provision of highway patrol vehicles and enforcement equipment as well as delivery of a training programme in traffic law enforcement to enforcement officers, the Police Department, and the nine municipalities.
- Road accident emergency services improvement through the provision of ambulances.
- Capacity building to help manage road safety through road safety mentoring (including assistance with the establishment of a National Road Safety Committee, development of the medium-term National Road Safety Strategy, road safety training and monitoring and evaluation.

The project will be managed by the Road Safety Unit. Task Leaders have been appointed from the various line ministries, who are responsible for coordinating, managing, and reporting to the Road Safety Unit on their assigned project components. This unit is overseen by an Operational Steering Committee (OSC) which is a decision-making forum to direct project activities, monitor the progress of project components, and resolve implementation obstacles. Above the OSC, the NRSC provides a high-level, multistakeholder guidance and advisory body to government on road safety.
This principle of stakeholder participation is central to the government’s approach. The project was launched in March 2013, with wide stakeholder participation in the event. Each year there will be an annual review which will provide the opportunity for formative evaluation. Based on what worked well, and not so well, and stakeholders’ inputs, a revised work plan will be devised for the following year. This will allow the shifting of resources and focusing on what is actually contributing to the overall intended project result. The cycle, then, is repeated each year.

The outcome: This project is still being evaluated, but early results are positive. Fatalities have reduced by about 26% on the demonstration corridor, whilst similar parts of the network registered a slight increase (3%).

Source: Caribbean Development Bank, Mavis Johnson, and iRAP.

There are also links that can be made with broader policy agendas, as illustrated by the example in Box 9.3

BOX 9.3: CASE STUDY – SPEED MANAGEMENT, ENVIRONMENT, SAFETY AND CONGESTION

The problem: Persistent air pollution problems in the Randstad (an agglomeration in the Western part of the Netherlands), particularly from nitrogen oxide (NOx) emissions, led the Dutch Government to experiment with reduced speeds on motorways in this densely populated part of the country.

The solution: In 2002, an 80 km/h zone was introduced on the A13, a motorway between The Hague and Rotterdam. The speed limit was reduced from 100 km/h to 80 km/h, which was strictly enforced by section control.

The outcome: This pilot project recorded a decrease of 4–6% of NO2 concentrations in the air, and a reduction of 10–14% for the contribution from traffic. The reduction in NOx emissions was about 13%. The speed reduction resulted in a decrease of more than 50% of injury crashes and had a positive effect on the traffic flow. Extension of the reduced limits resulted in promising early reductions in emissions and positive effects on traffic safety and noise.


As a further example, asset management involves maintaining and upgrading road infrastructure, and this typically has road safety implications. It is often the case that planning and funding for asset management and road safety outcomes occur in isolation, and without adequate linkages between the two. Both activities are closely linked, with each directly influencing the other. Adequate knowledge of the safety implications of asset decisions is required when establishing policy and practice. Similarly, safety decisions can have a substantial impact on asset management (particularly costs for maintaining assets).

When considered in isolation, the two road management approaches are often thought to act in conflict. There may be a perception that increases in funding for road safety may mean less funding or increased expenditure for asset management. However, there is some clear evidence that the two can act in harmony to produce benefits that are greater than those that can be delivered when considered in isolation.
Specific examples from LMICs are scarce, but the example in Box 4 from Australia serves to illustrate the level of benefits that can be gained through a coordinated approach. Combining the safety benefits with those from asset improvements can often lead to better project viability. This issue is discussed further in Roles, Responsibilities, Policy Development and Programmes.

**BOX 9.4: ASSET MANAGEMENT AND SAFETY OBJECTIVES CAN BE COMPLEMENTARY**

The Asset Management Branch of the Department of Infrastructure, Energy and Resources in Tasmania has developed a sustainable maintenance plan which is aimed primarily at preserving road pavement assets, including extending the lives of existing roads through pavement reconstruction, strengthening and resurfacing. Where an existing road is below departmental standards, cross-section improvements are usually made during reconstruction. This includes increasing the carriageway width, shoulder width and shoulder type, with sealing an option on some roads. Other elements, e.g. embankments, side slopes and drainage improvements, will also be undertaken.

As part of the analysis that underpins the Department’s plan, a study demonstrated that where pavement reconstruction was accompanied by cross-section improvements, in general, total crashes were considerably reduced, with an estimated social cost saving of approximately AUD$36 million. The corresponding marginal benefit cost ratios (MBCR) improved from 5 to 9 when these additional safety and travel time benefits were included (i.e. society could gain $8 compared to $4 per additional $1 invested when the safety benefits were added). The significant increase in MBCR was because many of the benefits were not being counted, i.e. the asset managers did not account for the safety and travel time benefits of their programme, noting that 89% of the additional benefits were due to estimated crash reductions.

Whilst this is clearly a worthwhile achievement, the potential reduction in crashes for the whole network was identified as being up to five times greater if cross-section deficiencies were addressed independent of pavement reconstruction. Thus, maximising benefits requires consideration of total needs.
DEVELOPMENT OF POLICIES, STANDARDS AND GUIDELINES

Roles, Responsibilities, Policy Development and Programmes provides direction on the development of policies for road safety outcomes. This includes the need to understand current road safety problems through the analysis of data; and the development of a road safety plan that includes appropriate targets and interventions. The development of infrastructure policy follows the same process, and should be considered as part of broader road safety policy development.

GRSF (2009) provides advice for countries that are establishing road safety capacity (i.e. LMICs) in terms of their investment strategies (also see The Road Safety Management System), and this advice is useful for development of policies, standards and guidelines. The advice suggests that the initial focus for such countries should be targeted on high crash density demonstration corridors and urban areas. The value of this demonstration corridor approach has been discussed throughout this manual, including the case study from Belize in Box 2.

GRSF (2009) also discussed the need to review and benchmark safety policies and interventions with other countries, and that this should lead to the commencement and implementation of reforms. This advice is equally relevant to road agencies attempting to implement new infrastructure policies. In order to focus attention to the highest priority areas, and to build capacity through doing, policies to address crashes at these locations can be addressed as a priority. Similarly, awareness of successful approaches adopted in other countries, and movement towards such approaches is a valuable method.

Little guidance exists on the mechanisms for transforming road infrastructure safety policy into relevant standards and guidelines. Rather, there are a number of examples that highlight what can be achieved. Many countries have developed their own standards and guidelines, and in some cases these may be adopted for use in other countries (although as noted elsewhere, caution should be used where the context is different). Croft et al. (2010) provide some advice based on the development of national guidelines in Australia. Some of the key elements from this process were that these were produced:

- under the direction of a review panel or task force;
- based on review of existing guidelines and related technical documents;
- so as to incorporate new strategic directions (e.g. the Safe System design principles);
- to include relevant research results, technological developments and practitioner experience.

There is a need to constantly review standards, policies and guidelines, and to improve these based on recent innovations. An evidence-based approach is required to ensure that expected safety benefits from any changes are attained. Benchmarking of approaches used in countries that perform well in safety is a good step to helping identify possible innovations. Further analysis may be required to ensure that changes will have a positive safety benefit when applied in a different country. Demonstration projects to trial new innovations are useful to establish whether such changes are beneficial in a controlled environment. Once evaluated and shown as successful these can be applied more broadly, and recommended changes reflected in appropriate guidance documents.

EXAMPLES OF INFRASTRUCTURE POLICIES, STANDARDS AND GUIDELINES

There is no set template for the development of policies, standards and guidelines, and those countries that do have comprehensive coverage of these vary in content, often reflecting local conditions. For those who wish to develop or improve policies, standards and guidelines it is beneficial to benchmark against good performers and draw upon international and regional examples of good practice. The sections below

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outline examples at global, regional and country levels, and may serve as a starting point in this exercise.

**GLOBAL LEVEL**

There has been a significant shift in road safety policy in recent years in response to the Safe System approach. This issue, including the origin of the approach and its implications, are discussed in detail in *The Safe System Approach*. The Decade of Action for Road Safety, described in *Key Developments in Road Safety*, has also resulted in some significant policy shift. At the international level, the UN Road Safety Collaboration (UNRSC) has developed a Global Plan that includes policy guidance on safe roads and mobility (also see *The UN Decade of action and global plan*). The plan states that the purpose of this pillar is to:

Raise the inherent safety and protective quality of road networks for the benefit of all road users, especially the most vulnerable (e.g. pedestrians, bicyclists and motorcyclists). This will be achieved through the implementation of road infrastructure assessment and improved safety-conscious planning, design, construction and operation of roads.


The plan suggests that this can be achieved by six key activities, namely to:

- promote road safety ownership and accountability among road authorities, road engineers and urban planners;
- promote the needs of all road users as part of sustainable urban planning, transport demand management, and land use management;
- promote safe operation, maintenance and improvement of existing road infrastructure;
- promote the development of safe new infrastructure that meets the mobility and access needs of all users;
- encourage capacity building and knowledge transfer in safe infrastructure;
- encourage research and development in safer roads and mobility.

Details on how each of these activities might be delivered can be found in Box 9.5. Individual countries will need to assess how they respond on each of these activities, but the information provides a useful checklist of actions that can be undertaken to improve the management and delivery of safe roads.
BOX 9.5: PILLAR 2 OF THE GLOBAL PLAN: SAFER ROADS AND MOBILITY

**Activity 1** Promote road safety ownership and accountability among road authorities, road engineers and urban planners by:

- encouraging governments and road authorities to set a target to eliminate high risk roads by 2020;
- encouraging road authorities to commit a minimum of 10% of road budgets to dedicated safer road infrastructure programmes;
- making road authorities legally responsible for improving road safety on their networks through cost-effective measures and for reporting annually on the safety situation, trends and remedial work undertaken;
- establishing a specialist road safety or traffic unit to monitor and improve the safety of the road network;
- promoting the Safe System approach and the role of self-explaining and forgiving road infrastructure;
- adhering to and/or fully implementing the regional road infrastructure agreements developed under the auspices of the United Nations regional commissions and encourage the creation of similar regional instruments, as required;
- monitoring the safety performance of investments in road infrastructure by national road authorities, development banks and other agencies.

**Activity 2** Promoting the needs of all road users as part of sustainable urban planning, transport demand management and land-use management by:

- planning land use to respond to the safe mobility needs of all, including travel demand management, access needs, market requirements, geographic and demographic conditions;
- including safety impact assessments as part of all planning and development decisions;
- putting effective access and development control procedures in place to prevent unsafe developments.

**Activity 3** Promote safe operation, maintenance and improvement of existing road infrastructure by requiring road authorities to:

- identify the number and location of deaths and injuries by road user type, and the key infrastructure factors that influence risk for each user group;
- identify hazardous road locations or sections where excessive numbers or severity of crashes occur and take corrective measures accordingly;
- conduct safety assessments of existing road infrastructure and implement proven engineering treatments to improve safety performance;
- take a leadership role in relation to speed management and speed sensitive design and operation of the road network;
- ensure work zone safety.

**Activity 4** Promote the development of safe new infrastructure that meets the mobility and access needs of all users by encouraging relevant authorities to:

- take into consideration all modes of transport when building new infrastructure;
- set minimum safety ratings for new designs and road investments that ensure the safety needs of all road users are included in the specification of new projects;
- use independent road safety impact assessment and safety audit findings in the planning, design, construction, operation and maintenance of new road projects, and ensure the audit recommendations are implemented.

**Activity 5** Encourage capacity building and knowledge transfer in safe infrastructure by:
• creating partnerships with development banks, national authorities, civil society, education providers and the private sector to ensure safe infrastructure design principles are well understood and applied;
• promoting road safety training and education in low-cost safety engineering, safety auditing and road assessment;
• developing and promoting standards for safe road design and operation that recognize and integrate with human factors and vehicle design.

**Activity 6** Encourage research and development in safer roads and mobility by:

• completing and sharing research on the business case for safer road infrastructure and the investment levels needed to meet the Decade of Action targets;
• promoting research and development into infrastructure safety improvements for road networks in low-income and middle-income countries;
• promoting demonstration projects to evaluate safety improvement innovations, especially for vulnerable road users.

Still at the global level, the UNRSC (2010) in their Safe Roads for Development document highlight some priority infrastructure policies, particularly in relation to LMICs. They suggest that priority crash types be targeted on high risk roads. Crash types include those involving vulnerable road users walking or cycling across or along the road; head-on crashes; side impacts at intersections; and run-off-road crashes. High risk roads refer to the small proportion of the world’s roads where the majority of fatal and serious injury crashes occur. They highlight that in the UK, just 10% of roads account for more than half of all road deaths, and around a third of all serious injuries. They also suggest that in Bangladesh, 3% of the arterial road network accounts for 40% of road deaths.
The priority actions for these roads and crash types include that:

- cities and communities should be planned for the growing number of people who do not own a car (i.e. vulnerable road users);
- planning and provision for vulnerable road users should include:
  - land use control;
  - widening and repair of footpaths;
  - enforcing laws to prevent vehicles from parking on footpaths;
  - removing barriers and street furniture on footpaths;
  - improvements to pedestrian crossings;
  - influencing land use planning alongside major roads (i.e. linear development).

Linked to this international policy context, a number of global guidelines have been produced to help address road safety. Produced by the World Health Organisation (WHO), Global Road Safety Partnership (GRSP), FIA Foundation and the World Bank, guidelines exist on various elements linked to road safety infrastructure. Of greatest interest to the audience of this manual are the guidelines on data systems (as discussed in Effective Management And Use Of Safety Data), and speed management and pedestrian safety. Other global guidelines exist on helmets, seatbelts, child restraints, and drinking and driving. All of the guidelines can be downloaded from the WHO website (http://www.who.int/roadsafety/publications/en/).

PIARC (2012) conducted an important review of national road safety policies and plans. This addressed policies for infrastructure improvements, and included the following key conclusions:

- A better understanding is required regarding the linkage between infrastructure and speed.
- A mixture of ‘spot location’ and system-wide approaches are used in different countries (and within countries). There is a place for both approaches, but there needs to be recognition that the current system is generally not safe.
- Risk assessment processes (Road Assessment Programmes are specifically identified) are highly beneficial, not only in identifying risk locations (including when crash data is not adequate), but also in identifying treatments. The process is also useful to help raise awareness about road features that contribute to risk, and how some treatments can be more effective than others.
- There is a need to conduct network-wide assessments, and prioritise action based on potential benefits.
- Comparing crash rates to an average for the network might not result in substantial safety investments, as this approach will generally maintain the average.

This current document is obviously the key guidance document produced by PIARC on road safety infrastructure. In addition, there are many other important documents relevant to road safety policy and guidance that can be accessed from the PIARC website (http://www.piarc.org/en/knowledge-base/road-safety/publications-safety/). These cover design and development of road infrastructure, road safety audits, safety on construction zones, vulnerable road users, road operation, road safety in winter conditions, road tunnels and others. The documents include those listed in Box 9.6.
**BOX 9.6: PIARC ROAD SAFETY PUBLICATIONS (2008-2013)**

- Road accident investigation guidelines for road engineers (2013 – 2013R07EN)
- Comparison of national road safety policies and plans (2012 – 2012R31EN)
- Road safety inspection guidelines for safety checks of existing roads (2012 – 2012R27EN)
- Human factors in road design. Review of design standards in nine countries (2012 – 2012R36EN)
- Best practices for road safety campaigns (2012 – 2012R28EN)
- Taking advantage of intelligent transport systems to improve road safety (2011 – 2011R03EN)
- Road safety audit guidelines for safety checks of new road projects (2011 – 2011R01EN)
- PIARC catalogue of design safety problems and potential countermeasures (2009 – 2009R07EN)
- Tools for road tunnel safety management (2009 – 2009R08EN)
- Human factors and road tunnel safety regarding users (2008 – 2008R17EN)

As well as supporting the UNRSC in the development of the Global Plan, the World Bank Global Road Safety Facility has produced a number of policy and guidance documents, many aimed specifically for use in LMICs. Comprehensive resources to assist in the delivery of safe road infrastructure can be found on the Facility’s website ([http://go.worldbank.org/9QZJ0GF1E0](http://go.worldbank.org/9QZJ0GF1E0)).

**REGIONAL LEVEL**

Regional policy for the delivery of safe infrastructure can also be found, most notably in the EU Directive 2008/96/EC. Issued in November 2008, this directive covers the trans-European road network, although it is suggested that the provisions of the Directive can be applied to the national road network. Separate European guidance on the secondary road network can also be found (see e.g. Polidori et al., 2012).

Provisions of the Directive include that:

- road safety impact assessment be carried out on all infrastructure projects on the trans European network. These are designed to assess the impact on safety of different planning alternatives;
- road safety audit be conducted on all infrastructure projects. Such audits should be conducted at the draft design, detailed design, pre-opening and early operation stages;
- safety ranking be undertaken in order to identify roads with a higher than average crash risk;
- data systems be put in place to collect information on fatal crashes, and calculate the average social costs of fatal and serious injury crashes.
The Directive also highlights the need to adopt guidelines to support these activities, and provides content on appropriate training, exchange of best practice and continuous improvement. A recent review of the Directive (European Commission, 2014) indicated that more systematic processes had been put in place in EU countries to safely manage infrastructure as a result of the Directive.

Further details on the approaches highlighted above can be found in Assessing Potential Risks And Identifying Issues.

Regional approaches to road safety in LMICs have also been developed, often under the Development Bank, UN Regional Commission, or regional economic grouping leadership. As an example, the Asian Development Bank (ADB) has developed a Sustainable Transport Initiative that directly addresses road safety through a Road Safety Action Plan for the region (www.adb.org/documents/road-safety-action-plan). This discusses the mainstreaming of road safety within areas of ADB operations. An ADB Road Safety Group has been established, and one of the objectives of this group is to make available key reference documents, terms of reference, guidance, and tools for use by those in the region. The summary document ‘Improving Road Safety in Asia and the Pacific’ provides useful advice and reference material on road safety based on recent ADB experience (see http://www.adb.org/sites/default/files/evaluation-document/36104/files/road-safety.pdf).

Box 2.4 in Key Developments in Road Safety describes the regional approach that was taken in the development of the African Road Safety Action Plan (2011–20). The development of this plan involved a wide range of stakeholders. At the country level, different approaches have been taken to the development of policy, and provision of relevant infrastructure standards and guidelines. This is often in response to different local context, including different legislation or safety issues. As identified elsewhere in this manual, there is typically no one correct approach to successfully managing road safety. However, there are often general principles that are universal.

**COUNTRY LEVEL**

In the United States, the Highway Safety Manual (AASHTO, 2010) provides detailed guidance on the roadway safety management process. The approach proposed is broadly aligned with that used in many countries, and it is no coincidence that the approach mirrors the structure of Planning, Design and Operation of this manual, particularly Assessing Potential Risks And Identifying Issues to Monitoring and Evaluation of Road Safety. The process includes keys steps, from network screening (identifying and ranking sites) to safety effectiveness evaluation (monitoring effectiveness).

Pre-dating the Highway Safety Manual, AASHTO produced a series of guides to assist in the delivery of the Strategic Highway Safety Plan. This comprehensive suite of 20 guides provides direction on key strategic issues. Those relating to road infrastructure include: guides on addressing collisions with trees in hazardous locations, head-on collisions, unsignalised and signalised intersections, run-off-road collisions, collisions on horizontal curves, utility poles, pedestrians and work zones. These documents can be downloaded from the Highway Safety Plan website (http://safety.transportation.org/guides.aspx).

Other countries have a similar set of guidelines to advise on effective road safety infrastructure management. For example, the Austroads Guide to Road Safety (currently in nine parts) provides guidance for Australia and New Zealand (see www.austroads.com.au); the Dutch have the Road Safety Manual (CROW, 2009) and Advancing Sustainable Safety (Wegman & Aarts, 2006); and the UK has the Good Practice Guide (DTLR, 2001). These documents are accompanied by many other relevant standards and guidelines in each country. As an example, Certu, the Centre for the study of urban planning, transport and public facilities in Lyon, France has produced a number of guides and reference documents (some of which have been translated into English; see http://www.territoires-ville.cerema.fr/). Also from France is the Transportation Safety in Urban Area: Methodological guide (Certi, 2008; available in French and English).
Although all of these documents are technically sound and serve as a useful basis for infrastructure safety management, as identified above, care should be taken when translating these guidelines to other countries. Different approaches, and particularly different solutions, may be more appropriate when the context (including traffic mix) is different.

As already identified in this section, different policies or guidance are sometimes issued for roads of different function. The EU Directive only refers to the trans-European road network, while additional information is available for lower order roads (see e.g. Polidori et al., 2012 for guidance on the secondary road network). Although the general principles that apply to each type of road are the same, often the detail can be different. Similarly, some countries issue guidance for local roads, recognising that the constraints can be different. Examples include The Good Practice Guide from the UK (DTLR, 2001); FHWA guidance in the United States on Developing Safety Plans: A Manual for Local Rural Road Owners (Ceifetz et al., 2012); and the Local Government and Community Road Safety guide (Austroads 2009; also see Austroads 2010a). McTiernan et al. (2010) also provide useful guidance on development of the Safe System approach for local government in Australia. However, usually only one guidance document exists covering road safety management of all roads, with those managing different parts of the network expected to adapt the information to their own circumstances.

ROAD DESIGN AND TRAFFIC MANAGEMENT GUIDELINES

Along with guidance documents targeted at safety-related topics (discussed in Examples of Infrastructure Policies, Standards and Guidelines in Policies, Standards and Guidelines and Intervention Selection And Prioritisation) many countries have comprehensive guidance on the design, construction, traffic
management and maintenance of roads. These typically embed safety, although it is noticeable that many have not yet fully embedded Safe System principles. Guidelines are often slow to include innovative approaches to road design, as these may take a number of years to construct and evaluate; there may be infrequent updates of guidelines; and there may be reluctance to change established practice. An evidence-based approach is required, as well as a process to facilitate continual improvement and updates to guides.

It is not possible to include comprehensive advice in this document on issues relating to road design, traffic management and maintenance, but rather readers are directed to appropriate country-based guidelines for this detail. As for safety-related guidance, countries are encouraged to benchmark against good performers (i.e. those with low crash rates) when developing or updating their own guidance.

Road design and construction involves the geometric design, and structural design of the roadway. A key objective of geometric road design is to optimise operational safety and transport efficiency within constraints (including budgets, environmental concerns and other social outcomes). Design needs to take into account the traffic volume and type of traffic expected to use the road. The elements that are typically thought to impact on efficiency and safety include intersections, horizontal curves, vertical curves and gradients, cross-section (lane and shoulder width, medians and roadsides), and merge/diverge areas, and design guides typically cover these issues in detail. Information is available on the influence of different design elements and the impact this has on safety outcomes (e.g. AASHTO, 2010; Harwood et al. 2014; Austroads 2010b).

The following points provide a brief description of effective countermeasures and the safety benefits of different design elements based on the above references. It is important to note, however, that although these treatments have a known effectiveness in reducing crash risk in HICs, it may be a different case for LMICs. For example, wider sealed shoulders may provide additional space for drivers to recover after a driving error, but in LMICs this area may be utilised by the community to set up a roadside stall.

Design criteria include:

- Design speed: The selected design speed influences the characteristics of various geometric elements on a roadway, such as lane widths, horizontal and vertical curves, and sight distance. The speed selected should reflect the speed drivers expect to travel at on a section of roadway, and should take into account the abutting developments, the roadway function and its physical limitations (due to terrain, expected traffic volumes, etc.).
- Lanes and shoulders: Crash risk can be linked to the total seal width (lane and shoulder seals). Crash risk
decreases with increasing seal width (i.e. wider lanes and larger shoulders), as the sealed area provides a recovery zone for errant vehicles and space for evasive manoeuvres. For two-lane rural roads, shoulder sealing can reduce crash risk by up to 35%.

- Horizontal alignment: This involves the design of horizontal curves along a road. Crash risk increases with decreasing curve radius (i.e. as a turn gets tighter). The risk increases more rapidly for curve radii below 400m. The crash risk is also higher for isolated curves (or where the driver might not be expecting it), and lower for curves in a sequence of similar-standard curves.

- Vertical alignment: This involves the road grade (the rate of change of vertical elevation) and vertical curves (i.e. crests and sags). Sag curves are not known to have any significant effect on safety. The most crucial effect crests have on safety is through sight distance, which is covered in the next bullet point. There is a small relationship between crash risk and vertical grade – the crash risk also increases more rapidly for grades beyond 6% as vehicle speeds becomes more difficult to manage.

- Stopping sight distance: This is the distance required for a driver to recognise a need to stop and brake to a stop from a particular speed. Horizontal and vertical curves limit a driver’s sight distance, particularly crests. There is the suggestion of a small increase in crash risk as sight distance over a crest decreases. This risk increases more rapidly for sight distances below 100m. Road widening (either as wider shoulders or an overtaking lane) over a crest with less than adequate sight distance can be an effective countermeasure rather than flattening the crest. It is suggested that safety is unlikely to be affected by limited stopping sight distance; however improving limited sight distance at locations where other vehicles may be slowing or stopping (in particular intersection sight distance) can be extremely important for safety.

- Roadside clearance: Also known as horizontal clearance or lateral offset, roadside clearance is distance between the edge of the roadway or shoulder to a vertical roadside obstruction, and the type of obstruction a vehicle might hit. Crash risk can potentially be reduced by 35 to 45% when all roadside hazards are removed (e.g. trees, poles, fences, etc.); however a barrier installation can be an effective countermeasure for reducing run-off-road crashes. It should be noted that a ‘clear’ roadside must also be flat or mildly sloping (e.g. 1:4 or flatter), and that roadsides with steeper gradients can have a large impact on vehicle safety.

The following references provide examples of road design guidelines from different countries:


- The United Kingdom has the Design Manual for Roads and Bridges (DMRB) available from [www.dft.gov.uk/ha/standards/dmrb/](http://www.dft.gov.uk/ha/standards/dmrb/).


- Towards Safer Roads in Developing Countries, produced by TRL in the UK provides very useful information on designing for safety, and is targeted at those in LMICs (see [http://www.transport-links.org/transport_links/publications/publications_v.asp?id=826&title=TOWARDS+SAFER+ROADS+IN+DEVELOPING+COUNTRIES](http://www.transport-links.org/transport_links/publications/publications_v.asp?id=826&title=TOWARDS+SAFER+ROADS+IN+DEVELOPING+COUNTRIES)).

- In South Africa SANRAL has produced the Geometric Design Guide ([http://www.nra.co.za/content/GDGeometricDesignGuide.pdf](http://www.nra.co.za/content/GDGeometricDesignGuide.pdf)).

Traffic management concerns the safe and efficient movement of people and goods. This includes provision for pedestrians, cyclists and other vulnerable road users. Again, many guidelines exist to assist in management of roads and traffic, and these typically relate closely to design principles, the capabilities of road users, and to vehicle characteristics. Guidelines typically cover aspects such as traffic theory, traffic studies and analysis, and the use of traffic control devices (signs, line markings) and other associated measures (traffic signal operation and street lighting). They may also cover issues such as speed management and traffic calming, public transport facilities, parking and management at roadworks.

Example guidelines include:

- In the United States there is the Manual on Uniform Traffic Control Devices (known as the MUTCD) – see http://mutcd.fhwa.dot.gov/index.htm
- Australia has produced the Austroads Guide to Traffic Management, covering 13 parts (www.austroads.com).

Typically design guidelines are prepared with an underlying assumption that they will be used where there are minimal constraints in delivering the project. These are sometimes referred to as ‘greenfields’ sites and the Normal Design Domain (NDD) design criteria should be used. However, it is far more common to make safety or other improvements at locations where constraints do exist, such as upgrades to existing roads, or ‘brownfields’ sites. Constraints can include things like an existing road alignment, utilities (including poles), drainage, access points, etc. In these situations, applying NDD values can make projects financially unviable. In addition, there may be cultural, heritage or environmental issues that limit application of NDD standards.

Many jurisdictions have developed procedures for dealing with departures from the NDD. When deviating from recommended design criteria, an exception report is required. This should be produced early in the design stage, and it should include clear and careful consideration of the safety impacts of any departure, as well as the impact on traffic operations. Mitigating strategies to minimise any adverse risk from the exception should also be provided.

Guidance on safety impacts resulting from departures in the NDD can be found in several countries, along with information on mitigation strategies. Useful examples include guidance by the New Jersey Department of Transportation (2012); the Queensland Department of Transport and Main Roads (2013) and Stein and Nueman (2007).

One recent approach from the United States (but also applied in other locations using different names) is the concept of ‘performance-based practical design’ (PBPD), which has evolved from the ‘practical design’ approach. This involves designing projects to stay within identified needs, and removing non-essential elements. This has the effect of lowering costs, and enabling improvements at a greater number of locations. The move to a ‘performance-based’ approach means that informed decisions will be made using analysis tools (for example, the Highway Safety Manual). Agencies using PBPD would have specific, long- and short-term, performance goals that may apply to a project, a whole corridor, or the overall system. Using available performance-analysis tools and qualitative assessments, projects would only include those features that serve those long- and short-term performance goals. Projects would not need to include features that provide performance exceeding the stated goals, fail to serve those performance goals, or are inconsistent with the purpose and need. This removes a concern relating to Practical Design that agencies may overemphasize short-term cost savings without a clear understanding of how such decisions would impact other objectives (such as safety and operational performance, context sensitivity, life-cycle costs, long-range corridor goals, liveability, and sustainability).

PBPD is a philosophy of balancing project purpose and need, design standards, life-cycle costs, operational
and safety performance and sustainability. To gain the greatest benefit from PBPD, it is highly encouraged to take a system-wide perspective and incorporate PBPD concepts in all decisions related to planning, programming and project development. Starting at the planning and programing phase, a multi-disciplinary group can weigh the options and trade-offs to define performance goals and a focused project purpose and need that is used throughout the life of the project.
9.4 MANAGEMENT TOOLS

A variety of tools and approaches are available to assist in the delivery of infrastructure safety management. As with guidelines, some tools have been prepared for use at the global, regional or country level. In some cases, the tools developed in one location or country can be adapted for use in another, but extreme care needs to be taken to ensure that the new context is considered when doing this. The types of tools available for road safety infrastructure management are mentioned in brief here, with further details provided in other relevant sections of this manual.

Schermers et al. (2011) provides a useful summary of tools used in Europe (most of which are discussed in this document. Elvik (2011) suggests a framework for applying tools that are related to the stages of a road’s life cycle. The US has also developed a comprehensive suite of tools for road safety infrastructure management. These are briefly discussed in the example in Box 9.7
BOX 9.7: SAFETY ANALYST, USA

The Safety Analytical Tools developed in the United States include:

The **Network Screening Tool** identifies sites with potential for safety improvements through algorithms that identify areas of concern (e.g. higher than expected crash frequencies). In addition, high crash severities or a higher than expected rate of specific collision types can also be identified. These algorithms are effective for spot locations, as well as short and extended road segments.

The **Diagnosis Tool** identifies the nature of safety problems at specific sites. It is able to generate a range of data, including crash summary statistics, collision diagrams, collision pattern identification (including whether or not a collision type occurs at a higher than expected rate), and to conduct statistical tests for specific sites. Both engineering and human factors are integrated to identify safety concerns.

The **Countermeasure Selection Tool** helps in the selection of interventions to reduce crash frequency and severity at sites. This tool incorporates site-specific countermeasures that are recommended based on the site type, crash patterns, and specific safety concerns identified with the earlier Diagnosis Tool. Single or multiple countermeasures may be selected and appraised with the Economic Appraisal and Priority Ranking tools.

The **Economic Appraisal Tool** performs an appraisal of either specific countermeasures or different options at a site. Within this tool, a number of economic evaluations can be undertaken, including cost-effectiveness, benefit-cost ratio and net benefits. Safety-effectiveness is estimated via observed, expected and predicted crash frequency and crash severity, as well as crash patterns and expected crash reduction for specific countermeasures. Notably, the analysis results are consistent with requirements of the Federal Highway Safety Improvement Programme guidelines.

The **Priority Ranking Tool** ranks sites and proposed improvements according to the benefit and cost analysis conducted by the Economic Appraisal tool. The site and improvement rankings are determined through comparison of cost-effectiveness, benefit-cost ratio, net benefits, safety benefits, construction cost, number of total crashes reduced, fatal and severe injury crash reduction, and fatal and all injury crash reduction. The Priority Ranking Tool assists in the optimisation of projects and maximisation of benefits across sites.

The **Countermeasure Evaluation Tool** allows pre- and post-evaluations of safety improvements using the Empirical Bayes (EB) approach. In addition, this tool has the capability to evaluate changes in the proportion of collision types. Analyses can also be performed to evaluate the efficacy of individual or combined countermeasures and construction projects. A benefit-cost analysis is also available to assess the economic benefits of countermeasures or construction projects.

Further details on these tools can be found at: [http://www.safetyanalyst.org/](http://www.safetyanalyst.org/).

The tools identified in Box 9.7 follow the broad stages of infrastructure safety management identified in Introduction. Later chapters discuss each of the key tools. The tools referenced for different stages of road safety management include:

- Assessment of potential risk: A variety of tools exist to assist in the collection and analysis of crash and non-crash road safety data to assist in this task.
— Crash data: Establishing and Maintaining Crash Data Systems, discusses the establishment and use of crash data systems, and some of the useful tools that are desirable for such systems.

— Non-crash data: Non-Crash Data and Recording Systems, discusses non-crash data, including the need for systems to collect and analyse such information.

- Identifying issues: Traditionally, tools for the assessment of risk have been reactive, as they were based on a concentration of crashes over time. In recent years, more proactive tools have been developed to identify risk locations. Both reactive and proactive tools are required to provide a full assessment of risk. Tools and approaches include:

  — crash-based identification (Crash-based Indentification (‘Reactive Approaches’))
  — road safety impact assessment (Road Safety Impact Assessment in Proactive Identification)
  — road safety audit (Road Safety Audit in Proactive Identification)
  — road safety inspection (Road Safety Inspection in Proactive Identification)
  — road assessment programmes (Road Assessment for Safety Infrastructure in Proactive Identification).

- Intervention selection: A variety of tools are available to help in the selection of appropriate interventions to address road safety risk. These include various websites that provide information on possible treatments based on problems identified. Intervention Selection And Prioritisation discusses some of the tools that can be used to assist in the selection of these treatments.

- Prioritisation: Prioritisation tools exist to help conduct economic appraisals of different options at a location, or for different locations, and then to prioritise projects to help achieve the greatest benefits based on available budgets. This prioritisation process, as well as some of the tools that are available, are discussed in Priority Ranking Methods and Economic Assessments.

- Monitoring and evaluation: Monitoring and evaluation is an essential part of infrastructure safety management. A limited number of tools are available to assist in this task, including the Countermeasure Evaluation Tool as part of the Safety Analyst suite discussed above. Further details on the importance of monitoring and evaluation can be found in Monitoring and Evaluation of Road Safety.
A further example, this one from France can be seen in Box 9.8.
Since the early 2000s, France has developed and implemented a set of road safety approaches for infrastructure projects. This set of approaches is now outlined in the European Directive 2008/96 on road safety infrastructure management for French implementation projects.

A **Road Safety Impact Assessment** is carried out for all infrastructure projects at the initial planning stage before the infrastructure project is approved. It identifies the road safety considerations which contribute to the selection of the proposed solution and provides all relevant information necessary for a cost-benefit analysis of the different options assessed.

A **Road Safety Audit** of the design characteristics from a safety viewpoint is carried out for all infrastructure projects by a trained auditor or a team of auditors. Audits form an integral part of the design process of the infrastructure project and are carried out at different stages of the project: draft and detailed design, pre-opening and early operation. Where unsafe features are identified in the course of the audit, the design is rectified. When it is not rectified before the end of the appropriate stage, the reasons are stated by the authority in an annex of the report.

**Source:** Audits de sécurité routière (Sétra, 2012).

A **Road Safety Inspection** is carried out on the national road network for all existing roads in order to report on the details of the road, its surrounding area and the general environment that can influence the user’s behaviour or affect their passive safety and thus have repercussions on road safety. The concept is to provide a method that will help the operator to improve their network knowledge. Inspection visits are made by appropriately qualified personnel, to identify the main road safety issues, and to provide a fresh point of view on the system. The systematic inspection of a section of road thus consists of a quick and practical rating of the main configurations that may not be expected by the road user, considering all modes of transport.

**Source:** Démarche ISRI - Inspections de sécurité routière des itinéraires (Sétra, 2008)

**Safety of users on existing roads:** this approach, called SURE in France, is carried out on the national road network for all existing roads. It is a general method of which the main innovation is to explicitly and continuously provide a complete approach of road safety improvements, from the road safety issues study to the assessment stage via the implementation of treatments. The aim of this approach is to determine and implement adapted treatments for sections of road where the safety gain is potentially higher.

The SURE process is a practical application of the common road safety approach presented in Examples of Infrastructure Policies, Standards and Guidelines in *Policies, Standards and Guidelines*. The process involves the following steps:

- **Know:** an issues study is conducted on a network divided into sections of road in order to establish a hierarchy of these sections compared to the potential safety gains;
- **Understand:** a safety diagnosis and a set of treatments’ concepts are established for each selected section;
- **Take action:** among those treatments’ concepts, a number of treatments are chosen and the road operator undertakes the planning, development and realisation of those treatments;
- **Assess:** the treatments’ assessment and the monitoring of crashes on the selected road section and its zone of influence are realised.

**Sources:** Démarche SURE (Sécurité des usagers sur les routes existantes) - Présentation et management (Sétra, 2006)
All of these tools can (and should) be used in parallel. Each is useful for different purposes, and for different stages of infrastructure safety management. Strengths and weaknesses are discussed in later chapters. Historically, the collection and analysis of crash data has been the most widely applied approach to managing safety. This is likely to continue to be an important approach, and is an important starting point for those in LMICs. Road safety audit and safety inspection are other widely applied tools, including in LMICs. One added advantage of these approaches is that they are a useful mechanism to improve safety culture.

One often over-looked issue is that the earlier within the safety management process, or project development process, the greater the potential to make a cost-effective improvement in safety outcomes. This is best demonstrated in the planning and development phase. In many countries road safety practitioners have historically relied upon road safety audit to determine safety issues in planning and development stages of design. In more recent times, tools to assist in embedding safety into design at the earliest stages have been developed. Importantly, some of these are aimed at practitioners who are not from a safety background in an attempt to include safety considerations into decision-making. These tools can be either quantitative in approach (such as tools that are based on crash prediction models) or qualitative. One of the most widely applied quantitative models is the US Interactive Highway Safety Design Model (IHSDM). This includes several modules, some of which can be used at the project development stage (AASHTO, 2010). It should be noted that this tool is generally applied to existing roads in the US, as very few new roads are built. Further information on IHSDM can be found in Box 9.10 and in Proactive Identification.

iRAP has also been used to quantify safety implications at the early design stage (see the case study in Box 9.9).

**BOX 9.9: CASE STUDY – ASSESSMENT AND IMPROVEMENT OF DESIGN PLANS – MOLDOVA AND INDIA**

The problem: New road designs are still being produced that result in significant numbers of deaths and serious injuries.

The solution: The iRAP star rating has been used in a number of countries to help improve design in order to achieve better safety outcomes. Examples include a pilot project in Moldova (the M2-R7 corridor - 116 km) and in India on the Karnataka State Highway Improvement Project (550 km). The projects were supported by the Millennium Challenge Corporation and the Global Road Safety Facility, respectively, as well as local and international partners.

Information was drawn from the road design plans prior to construction or rehabilitation to rate the safety of the proposed design. The iRAP star ratings score how road infrastructure influences the likelihood of crashes occurring and the severity of the crashes that do occur. The approach provides a simple and objective measure of the relative level of risk associated with road infrastructure for the
movements and manoeuvres that road users make. Different design options are compared, and the likely safety outcomes of different designs determined.

The outcome: The roads in Moldova and India show substantial improvements in safety based on the final designs implemented, notably for pedestrians in villages. Final designs for construction are anticipated to provide a reduction in severe injuries of 40% per year in Moldova and 45% in India. On the larger, busier, Indian network, this approximates to saving more than 100 deaths per year.

A fuller account of the project in India is available in Rogers et al., 2012.

The road assessment identified the need for pedestrian facilities and improved pedestrian safety. Following the assessment, provision for pedestrians was added to the design (including crossings, median refuge islands and sidewalks) and measures were included to slow traffic.

**Source: Case study provided by iRAP**
The problem: Idaho Transportation Department (ITD) identified deficiencies on Idaho State Highway 8 related to traffic operations, road geometry, access control and safety. Idaho State Highway 8 is an 11-mile two-lane highway traversing through rural residential and agricultural land uses. ITD wanted to conduct a corridor study to assess the existing traffic conditions, geometry, and to predict future crashes.

The solution: ITD used the Federal Highway Administration (FHWA) IHSDM software for this study. The IHSDM software is a package of analysis tools to evaluate the safety and operation of geometric design decisions on highways, and predict crashes based on the AASHTO Highway Safety Manual methodologies. The advantage of using the IHSDM provided the opportunity to perform a detailed review within the corridor on a number of critical elements at the same time (i.e. traffic operations, geometry and safety) to identify and target potential problem areas and develop effective mitigation strategies. Data requirements included crash data, existing roadway design plans, video, traffic control information, and traffic volumes (existing and projected). Information on expected crash reduction was used to compare effects of alternative treatment options. The list of mitigation strategies developed to address the identified issues was evaluated and prioritized.

The outcome: From the IHSDM output, ITD found more than half of the 11-mile corridor experienced a crash rate higher than the statewide average. The IHSDM Policy Review and Crash Prediction modules resulted in identifying geometric deficiencies, specific locations requiring further investigation, areas that required design improvements and safety issues on the corridor. A Corridor Plan Report was prepared which summarised the review, analysis and recommendations to be considered for potential improvement projects and programmed for implementation by the ITD over the next 10 years. Recommended mitigation measures consisted of passing lanes, intersection capacity improvements, sight distance improvements, roadside safety enhancements, intelligent transportation systems (ITS), animal crossings, and access management strategies.

Further information can be found on the FHWA website (http://safety.fhwa.dot.gov/hsm/casestudies/id_cstd.pdf).
The Strategic Tool for Assessment of Road Safety (STARS), developed in Australia, relies on checklists to help identify negative safety outcomes (Jurewicz, 2009). This approach provides a risk value to each of the checklist questions, and ultimately an overall safety rating for the planned project. Checklists are available for different stages of development, including regional or structure plans, master plans, sub-division or neighbourhood plans, arterial corridors, and new/commercial developments. Example road safety planning issues at the regional level include:

- Maximising public transport usage and minimising personal vehicle use - entails assessing ease of access to public transport through checking the location of activity centres in relation to public transport hubs (e.g. interchanges or train stations). It also involves assessing the location of major employment destinations and mixed land use prioritised around activity centres.
- Minimising traffic conflict along arterial roads - involves checking separation of arterial roads from residential areas and strip shopping centres, assessing whether the proposed plans support the control of vehicular access from arterial roads to adjacent lands and checking whether there is grade separation at level crossings.
- Maximising safe pedestrian and cyclist travel - involves assessing whether there are adequate and up-to-date provisions for pedestrians and cyclists and whether on- and off road facilities are planned for.

Further information on safety assessment prior to a road safety audit can be found in Road Safety Impact Assessment in Proactive Identification.

Road safety management tools need constant review as good practice and new approaches emerge. Elvik (2011) conducted such a review of European infrastructure safety management tools, and despite the many years of development and experience in using such tools, a number of opportunities for improvement were identified. Some of the key findings were that:

- There is a need to evaluate the effect on safety of road safety audit, safety inspection and road protection scoring, including the ability of these tools to identify safety solutions.
- The techniques adopted in the US Safety Analyst tool (see Box 9.7) for network screening should be used in Europe, and crash models should be used.
- The Empirical Bayes approach should be used in the selection of high risk locations (see Identifying Crash Locations in Crash-based Indentification (‘Reactive Approaches’)).
PATHWAY TO EFFECTIVE INFRASTRUCTURE SAFETY MANAGEMENT, POLICIES, STANDARDS AND GUIDELINES

GETTING STARTED

- A good understanding of infrastructure safety principles based on Safe System is required by key agency staff and stakeholders – from senior management through to technical staff.
- Review and internationally benchmark selected infrastructure safety policies and interventions, and commence implementation of reforms.
- Ensure safety is linked to broader transport policy, and safety is embedded within this policy.
- Assess the safety of high volume, high risk locations (e.g. high crash density demonstration corridors and urban areas) and implement multi-sector improvement programmes.
- Adopt tools for the management of road safety, and train key staff in the use of such tools.

MAKING PROGRESS

- Ensure all road agency staff have a good understanding of infrastructure safety principles based on Safe System principles. All staff, from senior management through to technical staff need this understanding, regardless of whether safety is the main focus of their role. This includes staff responsible for national, regional and local roads.
- Ensure that other stakeholders have good knowledge of infrastructure safety principles based on the Safe System approach.
- Implement ongoing reforms of safety policies and interventions, and introduce new measures in accordance with international good practice.
- Roll-out multi-sectoral measures (i.e. those that integrate infrastructure measures with e.g. enforcement, education, and post-crash care improvements), including across high risk corridors and urban areas.
- Continue to develop and tailor road safety tools, and ensure road agency staff and other stakeholders are adequately trained in the use of these tools.

CONSOLIDATING ACTIVITY

- Continue to develop the understanding of infrastructure safety based on Safe System principles amongst all agency staff, stakeholders and members of the public.
- Review and internationally benchmark safety policies and interventions, and implement reforms.
- Sustain comprehensive multi-sectoral measures across the whole road network and extend targeting to less risky roads.
- Continually improve road safety tools, and maintain high level of training and use amongst all stakeholders.
9.5 REFERENCES


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