Innovative guidelines and tools for vulnerable road users safety in India and Brazil [SaferBraIn]: D3.1 [v2] Measures, methodologies and tools

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<tr>
<td>AADT</td>
<td>Annual Average Daily Traffic</td>
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<tr>
<td>APM</td>
<td>Accident Prediction Model</td>
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<tr>
<td>BIKESAFE</td>
<td>Bicycle Countermeasure Selection System</td>
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<tr>
<td>CA</td>
<td>Canada</td>
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<tr>
<td>CBA</td>
<td>Cost-Benefit Analysis</td>
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<td>CH</td>
<td>Switzerland</td>
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<tr>
<td>DSS</td>
<td>Decision Support System</td>
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<td>DST</td>
<td>Decision Support Safety Tool</td>
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<td>GB</td>
<td>Great Britain</td>
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<td>gTKP</td>
<td>Global Transport Knowledge Partnership</td>
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<td>IHSDM</td>
<td>Interactive Highway Safety Design Model</td>
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<td>iRAP</td>
<td>International Road Assessment Programme</td>
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<td>NL</td>
<td>Netherlands</td>
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<td>NZ</td>
<td>New Zealand</td>
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<tr>
<td>PBCAT</td>
<td>Pedestrian and Bicyclist Crash Analysis Tool</td>
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<td>PCA</td>
<td>Pedestrian &amp; Cyclists Analysis</td>
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<tr>
<td>PEDSAFE</td>
<td>Pedestrian Safety Guide and Countermeasure Selection System</td>
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<td>RIA</td>
<td>Road safety Impact Assessment</td>
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<td>RPS</td>
<td>Road Protection Score</td>
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<td>RRRRAP</td>
<td>Road Restraint Risk Assessment Process</td>
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<td>RSA</td>
<td>Road Safety Audit</td>
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<tr>
<td>Abbreviation</td>
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<tr>
<td>UK</td>
<td>United Kingdom</td>
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<td>US</td>
<td>United States</td>
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<tr>
<td>VRU</td>
<td>Vulnerable Road User (in this case pedestrians or cyclists)</td>
</tr>
</tbody>
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**Key to symbols**

1. Unattended children
2. Mother-to-be
3. Parent with children
4. Pedestrian with walking aid
5. Partially-sighted
6. Blind pedestrian
7. Hearing-impaired or deaf-mute pedestrian
8. Pedestrian with pet
9. Pedestrian carrying loads
10. Senior pedestrians
11. Senior pedestrians with disabilities
12. Wheelchair user
13. Hawker, streetside vendor
14. Cyclist
15. PTWs rider
16. Driver
17. Animal-powered vehicle
18. Van, lorry
19. Transit
20. Emergency vehicle
1. Introduction

The aim of Work Package 3 is the definition of suitable measures, methodologies and tools to improve (safety) management of vulnerable road users in Emerging Economies.

One of the objectives is the definition of the requirements and functions for a VRU GIS-based oriented Decision Supporting System, which will facilitate the consideration of vulnerable user’s road safety in Emerging Economies. The DSS is suitable for the definition of the most suitable strategies and the identification of the most effective/efficient countermeasures, supporting the local technicians and decision makers in:

- Accident analysis
- Identification of main causes of accidents
- Identification of possible countermeasures
- Choice of most efficient countermeasures on the basis of cost-benefit analysis and cost-effective analysis
- Monitoring of results

This deliverable describes the results of an initial review about possible practices and methodologies to be included in the DSS or developed in the framework of SaferBrain. Especially the review focuses on: i) experiences and practices aimed at improving VRUs safety; ii) existing Decision Support Systems.

The aim of this deliverable is to synthesize the results of the reviews realised about these topics. The evaluation of their adaptability will be evaluated in subsequent activities of the Work Package 3 of SaferBrain and will be reported in another deliverable (D3.5).

Chapter 2 provides a review of existing experiences and practices aimed at VRU road safety, Chapter 3 synthesises a methodology developed in Europe for the assessment of pedestrian crossings safety and Chapter 4 provides a review of existing DSS’s and also gives a (first) overview of data need and the applicability of the DSSs on a local or regional level per DSS (description on a qualitative way). Chapter 5 provides short conclusions about the report.
2. Review of international experiences and practices aimed at improving VRUs safety

This Chapter provides examples of schemes aimed at improving the safe mobility of pedestrians and cyclists.

Predominantly, three types of scheme are considered: i) shared space, ii) prioritised space and iii) segregated space. Additional considerations are given to other traffic calming schemes/highway measures, specific schemes for child safety and VRU behaviour focused interventions.

2.1. Shared Space Schemes

The following schemes and initiatives bring vulnerable road users and motorised vehicles together in the same space, but use design features to encourage drivers to slow down and to be more aware of other road users. These schemes are typified by an overall reduction in formal traffic management. Traffic signs, lights and road markings are minimised, pedestrian barriers and signalised crossings are removed and in many cases level surfaces are used to create equal priority for all road users. These schemes are most appropriate in areas that already see high usage by vulnerable road users (Adams, 2008).

Shared space can be defined as “A street or place accessible to both pedestrians and vehicles that is designed to enable pedestrians to move more freely by reducing traffic management features that tend to encourage users of vehicles to assume priority” (Reid, Kocak & Hunt, 2009).

Figure 1: Shared Space


From a functional point of view, “Shared Space strives towards a design and layout of public spaces where traffic, residential and any other spatial functions are in balance with each other” (Keuning Instituut, 2005).

A shared space scheme differs from the other schemes described in this chapter, because rather than being technical, it is more a functional design process, in which the resulting spatial quality and improved social use are as important as the increased safety level such a scheme is primarily targeted to achieve.
2.1.1. The Design Process

Usually in urban consolidated environments, two typical situations call for the creation of shared spaces:

- **Potential public realms**: areas where freedom of movement and social exchange are endangered by motorised traffic, in spite of potentials as premium built environments or usual outdoor activities and functions (Figure 2).

![Figure 2: A potential public realm in Barcelona – Jaume I Square](image2)

- **Natural public realms**: areas where motorised flows are similar to the non motorised ones, and spaces are already spontaneously shared (Figure 3).

![Figure 3: A natural public realm in Rome – Caprera Square (3200 ped/day vs 4000 v/day )](image3)
In both cases, before creating a shared space, regulations are typical of those with mixed traffic schemes and drivers perceive themselves as the priority over the other traffic components.

Spaces can be shared either by non motorised modes, transit and private cars, or just by transit and non-motorised modes; differences may lay basically in the size of the space to be shared. For the former case, it is recommended to have small areas so to minimize conflicts between drivers and non motorised users (Figure 4).

![Figure 4: A square converted into shared space in the outskirts of Modena (Italy)](image)

For the latter, larger surfaces may be involved in the shared scheme (Figure 5).

![Figure 5: Shared space for non motorised modes and transit in Graz (Austria)](image)

Creating a shared space may become, therefore, a difficult task, as designers have to turn what is a new regulatory scheme (when applicable/enforceable) into an area where motorised and non motorised users are perceived to have the same rights. Moreover, it is worth remembering that in many countries, regulations for shared spaces are not even included in the National Highway Codes. As a consequence when creating a shared space, the focus switches to people rather than technical solutions, meaning by the former any kind of actor involved in the design process, the management approach and the regulations enforcement, from politicians to end-users.

Keuning Instituut (2005) provides a 9-cells model for the design process of a shared space, which may work as a kind of logbook to manage the issues above mentioned for both Potential Public Realms and Natural Public Realms.
The process operates on the diagonal (yellow cells) and white cells provide feedbacks/contributions/hints to the cells nearby. At the same time the model can play as a check to assess whether an area may qualify for such a scheme; for example if the design process is non-participative, creativity and special needs requirements may lag behind the technological solutions, and the final layout may be unsatisfactory for most end-users. A number of examples of the use of Shared Space have been published by Hamilton-Baillie. (2008a & 2008b).

### 2.1.2. Advantages

- Level surfaces can be beneficial to pedestrians with mobility impairments.
- Improved urban environments (easily adaptable to both central areas and outskirts).
- Freedom of movement for VRUs.
- UK schemes show no apparent safety reduction in terms of casualty numbers.

### 2.1.3. Disadvantages

Use of level surfaces and removal of features such as railings has been criticised by the UK Royal National Institute for the Blind, who have raised concerns about the safety of blind and partially sighted road users (Childs, Boampong, Rostron, Morgan, Eccleshall & Tyler, 2009; TNS-BMRB, 2010). However, it would be recommended to provide such cleared spaces with sensorial aids to guide visually-impaired users (see also sections on Adapting paths for Blind...
people). Further information on concerns is provided by the Guide Dogs for the Blind Association\(^1\).

Further work is also needed to consider the impact on other vulnerable groups such as young children and people with learning disabilities. Among the latter, dyslexic people are acknowledged to develop an alternative learning style and express preferences for a direct experience of learning and visualization of a given journey (Corrigan, 2001); to meet such a requirement it would be recommended to have the shared spaces equipped with elements (landmarks, posts, vegetation, urban furniture, etc.) as visual information to help dyslexic people, in substitution of text-based directions.

Although evidence is limited, UK data show no casualty reduction benefit.

Dutch evidence suggests that casualties may be greater for Shared Space Schemes compared to more traditional highway design, in areas with high traffic flows.

Hearing-impaired users accessing a shared space can be alerted by regular traffic signs, but they must pay a higher attention to motorised vehicles because of the mixed circulation scheme. The general layout of a shared space must include dedicated areas for local, usual outdoor activities as playing, selling and contemplate travel options to accommodate bus stops, bike shelters, etc.

Transit routes and schedules in areas with shared spaces should be planned considering prospective increase of pedestrian flows, which could cause detours or delays.

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\(^1\) [http://www.guidedogs.org.uk/sharedstreets/](http://www.guidedogs.org.uk/sharedstreets/)
2.1.4. Recommendations

2.2. Prioritised Space Schemes

2.2.1. Home Zones (UK) / Woonerven (NL) / Living Streets (UK & NZ) / Encounter Zones (CH), Zone 30 (F)

Home Zones23 are similar to Shared Space schemes, but often targeted specifically at residential streets, to create valued public spaces where traffic speeds are typically reduced to 16kph (10mph) or less. Focus is on community building, safety and encouragement of non-motorised travel. In northern Europe, application of these principles has also been applied to the design of shopping areas and public squares and spaces.

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2 http://www.homezones.org/homeUK.html
3 http://www.sustrans.org.uk/what-we-do/liveable-neighbourhoods/home-zones
The concept of Home Zones can be applied to existing infrastructure but is easiest to introduce within new-build schemes. Although referred to as Home Zones in the UK, the original concept originated in the Netherlands as the Woonerf, a low-density residential street where motorised vehicles are legally restricted to very low speeds (see Figure 8). A limit to a wider implementation of the Woonerf scheme is the mandatory requirement of very low vehicular flows (about < 10,000 v/day).

Other examples can be found across Europe, such as “VerkehrsberuhigterBereich” in Germany, which are similar low speed zones protected by traffic law, Zone 30 in France and “Encounter Zones” in Switzerland. In Scandinavian Countries and Germany, special schemes called Zone 15s (with the enforcement of 15 km/h speed limit) are also implemented in residential areas with mainly O/D vehicular flows (see Figure 9). A similar scheme with a 20 km/h speed limit has been implemented at historic centres of many Spanish urban areas (Figure 10).
After 10 years, the French lesson stresses some key parameters to support the decision-makers to plan Zone 30 schemes:

- Urban municipalities with at least 10,000 inhabitants should convert one or more areas into Zone 30s,
- Any area with commercial, residential, educational, leisure use may qualify to enforce a Zone 30 scheme,
- Zone 30s have a small extension/size: about 60% of the Zone 30s so far implemented in France are streets <500 m long,
- Key features to have a Zone 30 recognizable are: raised carriageways to have a common level surface of the whole area, entrance/exit specific signs,
implementation of traffic calming elements (mainly humps, pinch points, build-outs, roundabouts, etc.) (Pin & Rennesson 2003).

With the greater focus on speed reduction (often to walking speed, and except the UK, which is mandated in law), these schemes are typically seen as a form of prioritisation for non-motorists. This core principle is also embodied by similar Living Streets\(^4\)\(^5\) schemes.

2.2.1.1. Advantages

- Mandated vehicle speed reduction to very low speeds has clear safety benefits for vulnerable road users.
- Improved residential and commercial environments.
- Freedom of movement for VRUs.

2.2.1.2. Disadvantages

- Increased travel time for users of motorised transport
- Detours for commercial vehicles and transit
- Drivers may be resistant to enforcement of low speeds if treatment areas are extensive or vulnerable road user usage is low.

2.2.2. DIY Streets (UK)

DIY Streets\(^6\) is a UK project based on the Home Zones concept which helps people to redesign their own residential streets in a way that is cost effective, increases safety and improves the visual environment. It is a community led scheme focused on redeveloping existing streets in a cost effective and lasting way. The scheme was initially piloted in eleven communities across England and Wales and is now being used for large neighbourhood wide interventions. An example is shown in Figure 11.

![Before After](source: http://www.sustrans.org.uk/what-we-do/liveable-neighbourhoods/diy-streets/current-diy-streets-projects/clapton-terrace-hackney)

Figure 11: Example of a DIY Street

\(^4\)http://www.livingstreets.org.uk/
\(^5\)http://archived.ccc.govt.nz/programmes/livingstreets/
\(^6\)http://www.sustrans.org.uk/what-we-do/liveable-neighbourhoods/diy-streets/current-diy-streets-projects
2.2.2.1. Advantages

- Designed to be cost effective.
- Improved residential environments.
- Strong community involvement likely to increase local support for such schemes.
- A flexible approach intended to improve existing streets with minimal upheaval.
- Freedom of movement for VRUs.

2.2.2.2. Disadvantages

- Schemes based on existing infrastructure are clearly more limited than schemes that allow for total redesign.
- Some communities may be more difficult to engage in this process.

2.2.3. Community Streets (Japan)

Community streets and their evolution are a peculiar example of merging safety issues with requirements of comfort for pedestrians, and at a larger scale than the usual European cases. Implemented for the first time during the second half of the 1970s, in Osaka, Community streets were based on the reiteration of a simple scheme: the original 10m-wide carriageway was narrowed up to a one-way lane for cars, 3 m-wide, with repeated changes of alignment; the remaining part of the carriageway was converted into pedestrian areas, with a premium design layout including urban furniture, vegetation and public lighting, so to have a high quality residential environment (Figure 12). Such a scheme was replicated across the nation and then developed according to two main variations: a scheme especially designed for commercial areas and another one for recreational and school areas. The philosophy behind was that the conveyed feeling of ease and comfort due to such an upscale streets coping was meant to enhance the perception of safety among non-motorised users. In spite of the very high building costs, the program was successful and evolved into a kind of replicable scheme (the so-called “Road PIA”) for larger areas (up to 100 acres and more), even more expensive, with more emphasis on traffic calming and integration among non-motorised modes, transit and private traffic (Odani & Yamanaka 1990)
2.2.3.1. Recommendations
2.2.4. Bicycle Boulevards (US & CA)

Bicycle boulevards\textsuperscript{7} are essentially low volume low speed streets that have been optimized for bicycle travel (Figure 13). There is emphasis on formal traffic calming and highway treatments (in contrast to shared space schemes). Motorised traffic is reduced where possible (often limiting the space to local vehicles) and treatments are introduced to allow through movement of cyclists. Berkeley has a particularly strong record regarding the use of bicycle boulevards\textsuperscript{9} and has produced a clear set of guidelines on their design\textsuperscript{10}. A number of film examples of bicycle boulevards are available online\textsuperscript{11,12,13}.

![Figure 13: A Bicycle Boulevard in the US](http://www.ibpi.usp.pdx.edu/guidebook.php)

Source: http://www.ibpi.usp.pdx.edu/guidebook.php

2.2.4.1. Advantages

- Encourages bicycle use as roadway is optimised for cyclists.
- Designed for use by both experienced and inexperienced cyclists – and can help younger and novice riders to build their confidence.
- Also likely to increase pedestrian safety due to lower volume and speed of motorised traffic.
- Considered cheaper to implement than bike paths or trails.

2.2.4.2. Disadvantages

- May be difficult to introduce on roads with high speed traffic – segregation recommended for roads where travel speeds cannot be reduced to 30kph (19mph) or less.

\textsuperscript{7} http://www.ibpi.usp.pdx.edu/media/BicycleBoulevardGuidebook.pdf
\textsuperscript{8} http://www.bta4bikes.org/at_work/bikeboulevards.php
\textsuperscript{9} http://www.ci.berkeley.ca.us/ContentDisplay.aspx?id=6650
\textsuperscript{10} http://www.ci.berkeley.ca.us/ContentDisplay.aspx?id=6652
\textsuperscript{11} http://www.streetsblog.org/2007/01/24/streetfilms-berkeleys-bike-boulevards/
\textsuperscript{12} http://www.streetsblog.org/2006/10/31/street-films-portland-week-bicycle-boulevards/
\textsuperscript{13} http://www.streetfilms.org/bicycle-boulevards4nyc/
• Restrictions on motorists may not be considered acceptable by the driving community.

2.2.5. Contra flow Bicycle Lanes (UK, USA, Germany and others)

Bicycle lanes maybe used also as a kind of traffic calming element, on low traffic volume streets, by allowing bicyclists to travel the opposite direction of motor vehicle traffic on a one-way street (Figure 14). A number of examples of contra flow bicycle lanes can be found across Europe and the US. Detailed case studies and filmed examples are available online.

Figure 14: Contra flow bicycle lanes in London (UK), left, and in Frankfurt (Germany) right

2.2.5.1. Advantages

• Slow down vehicular traffic, especially when, on low traffic streets, drivers may be attracted to increase speed.
• Also likely to increase use of bicycles at a local level, as contra flow lanes may provide shortcuts.

2.2.5.2. Disadvantages

• Not to be introduced on roads with high speed traffic
• As contra flow lanes place cyclists in close proximity to opposite-direction traffic, making it harder to avoid collisions with vehicles that fail to yield when turning, special attention must be paid in designing conflicts areas (crossing areas and parking lanes).

14http://www.bikexpert.com/bikepol/facil/lanes/contraflow.htm
16http://www.streetfilms.org/the-capitols-colossal-contraflow-cycle-track/
2.2.5.3. Recommendations

2.3. Segregated Facility Schemes

Segregated facilities aim to minimize interactions between motorised vehicles and vulnerable road users by creating zones that cannot be accessed by most motor vehicles (exceptions may be made for emergency vehicles, vehicles delivering or collecting goods [loading] and certain forms of public transport), or that create facilities specifically for non-motorists where traffic is minimal.

2.3.1. Pedestrian Zones

Pedestrian zones\(^{17}\), also known as *auto-free zones* and *car-free zones*, are designed to allow safe and unrestricted travel on foot. They are particularly prevalent within town and city centre shopping areas.

\(^{17}\) [http://en.wikipedia.org/wiki/Pedestrian_zone](http://en.wikipedia.org/wiki/Pedestrian_zone)
Pedestrianisation of an area requires traffic to be re-routed. This can increase travel times and of course traffic flow on the alternative routes. Consideration must be given to whether VRU risks are being reduced or relocated. Where alternative routes go through residential areas, overall accident risk may not be reduced – particularly if the traffic follows unintended ‘rat-runs’ rather than using allocated roads that have been risk assessed (for increased traffic) and treated where necessary.

Most of the success of pedestrianisation relies on good access to the pedestrian zone. This includes public transport and available public parking at a convenient distance. ‘Park and ride’ (or ‘incentive parking’) schemes can be particularly beneficial, where out of town parking is provided in large compounds, with regular, low-cost public transport between the parking facility and the town centre. Other factors concurring to the success of pedestrianization are the quality of the built environment, the appropriate provision of urban furniture to meet the user needs (namely seats, lighting, and canopies or vegetation for shadow), the possibility to perform different activities (rest, stroll, play, buy, etc.) and to meet other people, thanks to a pedestrian-friendly layout, along with the general perception of security.

To support pedestrianization, traffic plans must also encompass some restrictions to car traffic as:

- Reduce on-street parking to a minimum.
- Stop through traffic, except for transit.
- Restrict access to the areas except for residents.
- Control deliveries.

As for Shared Spaces, in urban consolidated environments and especially in historical centres, alleys, streets and squares were born as pedestrian realms which prompted local administrators from many European cities to have scattered pedestrian areas reorganized into local pedestrian networks, resulting thus into an increased safety level, a major liveability and even an increased trade, on a larger scale (Figure 16).

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18 http://www.accesscode.info/external/5_12.htm
19 http://www.parkandride.net/
Figure 16: Switching from pedestrian zones to pedestrian networks (in blue): the lesson from Barcelona (Spain)

Cycling may or may not be permitted in pedestrian zones, depending on the location (Figure 17). Cyclists can of course dismount and walk through the zone if necessary. Although pedestrianised areas are considered safe for cyclists, the concern here is for pedestrians, as there are a small number of pedestrian fatalities every year from collisions with cyclists.

Figure 17: Cycling permission

Source: http://www.flickr.com/photos/bellavite/2363819015/

2.3.1.1. Advantages

- Increased pedestrian safety.
- Improved urban environments.
- Freedom of movement for pedestrians.

2.3.1.2. Disadvantages

- Restrictions on motorists may significantly increase their travel time.
- Without careful planning, may cause problems for people with restricted mobility.
- Loading restrictions can cause difficulties for businesses.
• Issues for residential properties within the restricted zone, in terms of access, parking, deliveries etc.

2.3.1.3. Recommendations

<table>
<thead>
<tr>
<th>Recommendable</th>
<th>Partly Recommendable</th>
<th>Neutral</th>
<th>Not Recommendable</th>
</tr>
</thead>
</table>

2.3.2. Cycle Networks

Cycle networks are often aimed at leisure cycling rather than commuting. They generally consist of cycle trails that are either entirely separate from the road network, or use very low traffic routes where necessary. By segregating cyclists from heavy traffic, their safety is increased. However, unlike bicycle boulevards, these routes may not be designed to be direct and efficient – with greater emphasis on the journey being scenic.

Examples of cycle networks include the National Cycle Network and the National Byway in Great Britain, and the EuroVelo across mainland Europe.
2.3.2.1. National Cycle Network (UK)

The National Cycle Network\textsuperscript{20} was created by Sustrans, a sustainable transport charity. It spans over 16,000km and although many of the routes are necessarily along roads, it includes the use of canal towpaths and disused railways to segregate cyclists from motorised traffic where possible.

![Figure 18: National Cycle Network in the UK](http://www.sustrans.org.uk/what-we-do/national-cycle-network)

Source: http://www.sustrans.org.uk/what-we-do/national-cycle-network

2.3.2.2. The National Byway (GB)

The National Byway\textsuperscript{21} is a signposted leisure cycling route around Britain, using existing rural lanes with only light traffic (2\% of the national average level). Currently under development, it spans over 7,000 km. There are approximately 1,000 historic sites and designated ‘places of interest’ along the way.

![Figure 19: National Byway Sign](http://wiki.openstreetmap.org/wiki/National_Byway)

Source: http://wiki.openstreetmap.org/wiki/National_Byway

\textsuperscript{20}http://www.sustrans.org.uk/what-we-do/national-cycle-network
\textsuperscript{21}http://www.thenationalbyway.org/welcome.asp
2.3.2.3. EuroVelo – The European Cycle Route Network

EuroVelo\(^\text{22}\), the European cycle route network, is a project of the European Cyclists' Federation (ECF) which will cover over 66,000km. It is made up of both existing and planned cycle routes that meet specific criteria, based on best practice from 12 different countries.

![Figure 20: EuroVelosignage](http://indjija-tourism.com/code/navigate.php?id=138)

2.3.2.4. Advantages

- Increased cyclist safety.
- Encourages cycling.
- Does not disrupt motorised traffic.

2.3.2.5. Disadvantages

- May not offer cyclists direct routes for commuting etc.
- Where routes are not continuous there is risk associated with joining busy carriageways.

2.4. Child Focused Schemes

Children are particularly vulnerable as cyclists and pedestrians. The European RoSaCe project\(^\text{23}\) was set up to improve street safety for children and there are a number of practical schemes that specifically target this VRU group.

2.4.1. Safe Routes to School

The Safe Routes\(^\text{24}\) scheme was set up to support children walking and cycling to school through education, engineering and enforcement. The concept originates from Denmark and has spread across Europe, Australia, New Zealand, Canada and the United States. For example, in 2005, federal transport legislation in the United States committed $612 million USD to a National Safe Routes to School Program.

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\(^{22}\) [http://www.ecf.com/14_1](http://www.ecf.com/14_1)

\(^{23}\) [http://www.rosace-europe.net/](http://www.rosace-europe.net/)

\(^{24}\) [http://www.saferoutesinfo.org/](http://www.saferoutesinfo.org/)
East Cleveland, Ohio provides a case example of how this program has been used within communities. It was an area identified as particularly dangerous for child pedestrians. Signals, signs and crossings were added and improved, and as a community initiative, students were helped to stencil their names in footprints painted throughout the crossings (Figure 22). These crossings were designed to draw the attention of drivers while also giving the students a sense of ownership.

The Lunetta Gamberini Junior School case study in Bologna, Italy, is similar to the Ohio case study, but it is worth reporting because of the methodology developed to direct the project. The analysis of what might be the safest routes to school started by asking schoolchildren to describe any dangerous situation they perceived in their everyday route to school, using a special questionnaire created by the teaching staff. Parents were asked to do the same, at home. The second step was to ask parents to help their children to draw on a map their everyday route to school and locate the dangerous situations (if any) they described in the questionnaire. The goal of this phase was to gain three different kinds of information: a) which were children’s most usual routes to school; b) knowledge of the children’s recurring fears due to factors as traffic, hostile environment, poor security, etc.; c), by asking the children to locate such dangerous situations on the map, to assess whether they really experienced them. The list of actual problems and the resulting map with the localisation of
the places where they usually occurred was compared to the local black spots map and accident data provided by the local police (Figure 23).

Figure 23: The most usual routes to the Lunetta Gamberini School in Bologna (Italy) and the recurring problems

The collection of all the different kinds of information allowed the municipal technical staff to plan a series of common routes to school, in which four basic safety measures were designed to solve problems highlighted by the questionnaire and the black spot analyses (Figure 24).
The four safety measures were 1) enlargement of sidewalks to accommodate the children flows to school; 2) re-design of mid-block crossing areas (by bollards and signs) to prevent children from jaywalking; 3) re-design crossing areas at junctions by protruding sidewalks; 4) as the school is located within a city park, with many entrances, and having children stressed their fear for the moped riders’ behaviour in the park, it was decided to design a special moped-free barriers at the park entrances (Figure 25).

A special effort was to keep the whole cost of the plan at a minimum; once implemented the final theoretical cost was about 65 Euro/child.

The Lunetta Gamberini Project was one of the first actions aimed at improving safety for schoolchildren in Italy; even though it was awarded by the Ministry of Transport and Infrastructure, it is still a one-off experience in Italy due to the difficulties in collecting data about children’s habits and redesigning infrastructures.

2.4.1.1. Advantages

- Increased safety for young VRUs.
- Encourages walking and cycling to school.

2.4.1.2. Disadvantages

- Can be expensive to treat all potential routes.
- Potential for VRUs to follow ‘desire lines’ rather than intended safe routes (also known as desire paths and social trails) – these are direct shortcuts that may be visible due to footprints or erosion.
- Requires regular commitment of teaching staff.
2.5. School Zones / School Safety Zones

A school zone\textsuperscript{26} is an area near a school where the speed limit is reduced – often during specific hours corresponding to children starting and finishing their school day.

![Figure 26: Signage for a School Zone](http://en.wikipedia.org/wiki/File:School_zone_flashing_light_warning_sign.jpg)


![Figure 27: Signage for a School Safety Zone](http://www.suffolk.gov.uk/TransportAndStreets/RoadSafety/SchoolSafetyZones.htm)

Source: http://www.suffolk.gov.uk/TransportAndStreets/RoadSafety/SchoolSafetyZones.htm

Characterised by clear signage, these zones may also use road markings and surface changes for maximum visual impact. Parking is often restricted within school zones, to further increase the safety of child pedestrians.

\textsuperscript{26} http://en.wikipedia.org/wiki/School_zone
2.5.1.1. Advantages

• Likely increased safety for young VRUs.

2.5.1.2. Disadvantages

• May find poor compliance amongst motorists when limits are set very low, particularly when low speed limits are permanent compared with when low speed limits are restricted to peak times (e.g. start and finish of school day).

2.5.2. Walking Bus / Bicycle Train

A walking bus\(^{26}\) is essentially an organised group of children walking to school under adult supervision. A bicycle train\(^{27}\) is based on the same principle but with supervised groups of cyclists. These can be run on a fairly informal basis or may be highly organised and timetabled. There are many local examples of these schemes across the UK\(^{28}\)^{29}.

\(^{26}\) http://www.walkingschoolbus.org/
\(^{27}\) http://www.hertshighways.org.uk/infobase/docs/pdfstore/cycletrain.pdf
\(^{28}\) http://www.kentwalkingbus.org/
\(^{29}\) http://www.leics.gov.uk/index/highways/road_safety/school_travel_plans/walking_bus_scheme.htm
Figure 30: Example of a Walking Bus


2.5.2.1. Advantages

- ‘Safety in numbers’.
- Encourages walking/cycling.
- Larger groups are more visible to motorists.

2.5.2.2. Disadvantages

- Requires regular commitment of volunteers (in all weathers) or teaching staff.
2.5.2.3. Recommendations

In any traffic environment, the risk of road user injury comes from a combination of highway, vehicle and human factors. Although the focus of this document is on highway schemes, it should be noted that there are key road user behaviour measures that can dramatically reduce the number of serious casualties.

It is essential that vulnerable road users have good road safety awareness, which can be developed through safety education (e.g. being able to identify when and where it is safe to cross the road, identifying likely hazards). In Britain for example, the Cycling Proficiency Test was introduced to encourage cyclists to meet a minimum recommended standard. This has now been re-launched as 'Bikeability'\textsuperscript{30}. ROSPA (2000) have produced formal guidelines on practical cyclist training schemes. There are also child pedestrian training schemes such as Kerbcraft\textsuperscript{31}.

Another key issue for vulnerable road users is their visibility. The use of high visibility clothing (Hi-Vis) or accessories (backpacks, armbands etc.) can dramatically increase the distance at which VRUs can be seen by motorists in the dark.

\textsuperscript{30} \url{http://www.bikeability.org.uk/}
\textsuperscript{31} \url{http://www.kerbcraft.org/}
Finally, protective clothing, in particular cycle helmets are important for protecting accident-involved road users from serious head injuries (Cook & Sheikh, 2000). Encouraging or even mandating cycle helmet use should be considered.

2.7. Selected safety measures for physically-challenged users

Physically-challenged users require specific safety measures, which usually turn out to be useful for other VRUs categories, too.

In particular even though scientific literature and specifications abound for wheelchair users and blind people, and laws and rules to accommodate areas and buildings in order to meet their requirements are compulsory in most countries, design solutions seem not always to be appropriate. Moreover, what seems to be suitable to a user of a wheelchair, may turn out to be unsuitable for people with other disabilities.

It is very difficult to design safety measures and, at the same time, to meet all the different requirements from people with walking, sight or hearing disabilities; for instance deaf-mute users are usually (and wrongly) left behind, since in many cases no specifications or regulations are compulsory, or there is a poor knowledge of their needs. A shared space, for example, may meet perfectly most requirements of people with walking impairments, but need extra adjustments to be used by people who do not see or hear a vehicle approaching.

Scientific literature on Universal Design in Italy (Lauria 1994, Vescovo 1997) provides some useful design solutions to improve road safety for physically challenged users, trying to reach a relative optimum for any kind of users.

The general advice is, however, to have whatever solution always tested by the users, so to have the final approval.

There are some general aspects to consider, before designing safety measures for physically-challenged users, such as:

- The provision of tactile paving may be not sufficient to provide information about the end of a running slope, especially if gentle and long; such a kind of slopes can be also not appropriate for people with canes or similar walking aids, who can find it generally difficult to walk on ramps. As a consequence, the crossing area on a sidewalk should be divided into two parts: the slope for wheelchair users and any other user who may find it beneficial (parents with prams); the grade for the others. It is recommended to have special paving (different colour and texture) in the areas approaching zebra crossings and to provide blind users with a single line of tactile tiles on the zebra crossing to show the centre of the crossing area (Figure 31).
Figure 31: Design solutions to accommodate both the visually impaired and wheelchair users

- Objects less than 20/25 cm-high are not easily detectable by the canes used by visually impaired people; it would be recommended to have posts/poles recognizable by a special treatment (Figure 32).

Figure 32: Detectable bollards
• On the contrary wheelchair users may appreciate information at eye level, or even on the ground, which in some cases can be beneficial also to people with hearing impairments (Figure 34).

Figure 34: The name of the street printed on the special concrete surface, Lombard St. S. Francisco (USA) left; alert warning at crossing in London (UK), right

• Traffic noise and vibrations can respectively alert blind people and deaf users of an approaching vehicle; rumble strips may work, as well also in case of conflicts with cyclists (Figure 35).
Figure 35: Rumble strips to alert pedestrians a vehicle is approaching

- A sequence of hearing, smelling and thermal “clues” may be perceived by blind people as a kind of “natural” guide and integrate instructions provided by tactile paving or maps. Shadows provided by vegetation or canopies may be a useful clue to alert blind users of crossing areas, bus stops, etc.
2.7.1.1. Recommendations
3. Methodology for pedestrian crossing safety assessment

The safety level of a pedestrian crossing is affected by infrastructure characteristics and vehicular and pedestrian traffic level. A methodology that allows assessing the safety level of a pedestrian crossing, regulated or not by traffic light, in an urban area according to the features of the crossing, has been recently developed (Basile et al., 2010).

The methodology has been used for the evaluation of 215 pedestrian crossings in 17 European cities for the Pedestrian Crossing Assessment Project co-financed by FIA Foundation.

The methodology allows assessing the safety level of pedestrian crossings in urban area based on an on-site inspection performed using ad-hoc data gathering forms. In detail, the research question relates to how to assign a safety rate to a pedestrian crossing on the basis of its various features and characteristics in order to define a priority list of interventions and to suggest which features need to be improved, as the specific contribution of a crossing feature to pedestrian safety level has been defined.

The approach undertaken consists in: problem definition and selection of safety evaluation criteria, weighting of criteria, definition of a composite indicator that expresses the safety level on the basis of crossing features.

3.1. Analysis methodology

Safety of a pedestrian facility depends on its features and on how it is used (i.e. pedestrian and vehicles traffic characteristics).

Models existing in literature are based both on traffic and pedestrian volumes information and on pedestrian crossing features, but in many cases traffic data are not available. The chosen approach focuses on safety of a pedestrian crossing, without taking into account existing traffic composition and volumes.

The risk is therefore not to select for intervention pedestrian crossings that show a high accident frequency due to higher traffic volumes. On the other hand the methodology permits to identify for intervention pedestrian crossings showing the worst characteristics.

A number of factors exist from literature that affect directly or indirectly pedestrian crossing safety. The relative weight of each factor can be defined through opinions by a panel of experts. The problem of finding the specific contribution of each factor to safety has been solved applying Analytic Hierarchy Process (AHP) method.

This method is generally used to compare different alternatives and evaluating which one is the best to satisfy a defined goal. For the purpose of the paper, AHP has been used to aggregate different experts’ opinions about contribution of every factor to safety.

A theoretical framework for safety has been defined including potential crossing safety related factors/features. Factors and features have been selected by a panel of experts on the basis of their relevance, perceived by the panel, and of results found in literature.

Due to significant differences in traffic rules and road users behaviour between signalized and not signalized pedestrian crossings, these two scenarios have been treated separately.

For each scenario the problem has been decomposed into three hierarchical levels. The first level represents the pedestrian crossing safety composite index.

The second level is defined by four macro-criteria contributing to safety of pedestrian crossings:
• Spatial and Temporal Design.
• Day-time Visibility.
• Night-time Visibility.
• Accessibility.

The third level contains the assessment criteria related to each of the four macro-criteria. Macro-criteria have been defined grouping identified criteria according to common objectives of good design principles.

Spatial and Temporal Design macro-criterion takes into account pedestrian exposure to traffic, conflicts and timing factors to assess the functioning of the crossing for the pedestrian. Included criteria aim at minimizing waiting time needed to find a crossing opportunity and time needed to cross safely for all road users, including limitation of traffic exposure, through the reduction of conflict points and segmentation of crosswalk.

Day-time Visibility and Night-time Visibility criteria evaluate visibility of pedestrians at crossing for motorists, visibility of the pedestrian crossing for motorists, and visibility of oncoming vehicles for pedestrians.

Accessibility criteria account for ensuring proper access for all road users, with or without disabilities, to approach the pedestrian crossing free of obstacles and possible dangers.

For each criterion a specific indicator has been identified. Indicators can refer to quantitative measures (e.g. roadway width) or qualitative measures (e.g. visibility conditions of pavement markings).

As different measurement units are present, indicators have been re-scaled in order to have a common range (0, 1). A value near to 0 is associated to safer situations, while a value near 1 is associated to risky situations.

For quantitative measures, re-scaling consisted in giving a distance from a reference value or in definition of indicators above or below a threshold. For qualitative measures, categorical scales that assign a score to possible indicator values have been used. Engineering design handbooks and research studies provide conditions for safe and correct design of a pedestrian crossing.

Selected criteria and related indicators are presented in Table 3.
AHP has been used to find a weight for each criterion present in the theoretical framework. According to this method, in case of a hierarchal structure with three levels defined by J criteria, M macro-criteria and a goal, it is necessary to evaluate:

- The weight $w_i^m$ of general criterion $A_i$ associated to general macro-criterion $C_m$.
- The weight $w_m$ of general macro-criterion $C_m$ contributing to the general goal (safety level).

All the weights are calculated by aggregating the results from a number of pairwise comparison square matrices, where the elements $a_{ij}$ of a matrix (also called “dominance coefficients”) represent the prevalence of criterion $A_i$ on criterion $A_j$ in reference to the corresponding macro-criterion/goal. A comparison matrix needs to be defined for each of the four macro-criteria and for the general goal.

### Table 1: Criteria and range values of related indicators

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>Range Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spatial and Temporal Design</strong></td>
<td></td>
</tr>
<tr>
<td>Roadway width</td>
<td>0: $&lt;=2.75$m; otherwise (1-2.75/m)</td>
</tr>
<tr>
<td>Pedestrian-vehicles conflict points</td>
<td>0.2: 1 conflict point; 0.4: 2 conflict points; 0.6: 3 or 4 conflict points; 1: $&gt;4$ conflict points</td>
</tr>
<tr>
<td>Painted or raised pedestrian refuge islands</td>
<td>0: refuge island width$&gt;1.5$m; 0.5: refuge island width$&lt;=$1.5$m; 1: no refuge island</td>
</tr>
<tr>
<td>(also designed for disabled people)</td>
<td></td>
</tr>
<tr>
<td>Pedestrian traffic light</td>
<td>0: Yes; 1: No</td>
</tr>
<tr>
<td>Green phase efficiency</td>
<td>0: phase sufficient for mobility disabled people; 0.5: phase not sufficient</td>
</tr>
<tr>
<td>Amber phase efficiency</td>
<td>0: phase sufficient for mobility disabled people; 0.5: phase not sufficient</td>
</tr>
<tr>
<td>Red phase duration</td>
<td>0: $&lt;=$60 sec; 1: $&gt;60$ sec</td>
</tr>
<tr>
<td>Pedestrian Countdown signal</td>
<td>0: Present; 1: Not present</td>
</tr>
<tr>
<td><strong>Day-time Visibility</strong></td>
<td></td>
</tr>
<tr>
<td>Minimum approach sight distance</td>
<td>0: sight distance $&gt;$ brake distance; 1: sight distance $&lt;$ brake distance</td>
</tr>
<tr>
<td>Pedestrian crossing signs visibility</td>
<td>0: Very good; 0.25: Good; 0.5: Sufficient; 0.75: Unsatisfactory; 1: Poor</td>
</tr>
<tr>
<td>Pavement markings visibility</td>
<td>0: Very good; 0.25: Good; 0.5: Sufficient; 0.75: Unsatisfactory; 1: Poor</td>
</tr>
<tr>
<td>Pedestrian crossing width</td>
<td>0: $&gt;2.5$m; 1: $&lt;2.5$m</td>
</tr>
<tr>
<td>Traffic direction signalization</td>
<td>0: Present; 1: Not present</td>
</tr>
<tr>
<td><strong>Night-time Visibility</strong></td>
<td></td>
</tr>
<tr>
<td>Light conditions</td>
<td>0: Very good; 0.25: Good; 0.5: Sufficient visibility; 0.75; Unsatisfactory visibility; 1: Poor visibility</td>
</tr>
<tr>
<td>Minimum approach sight distance</td>
<td>0: sight distance $&gt;$ brake distance; 1: sight distance $&lt;$ brake distance</td>
</tr>
<tr>
<td>Pedestrian crossing signs/signal visibility</td>
<td>0: Very good; 0.25: Good; 0.5: Sufficient; 0.75: Unsatisfactory; 1: Poor</td>
</tr>
<tr>
<td>Pavement markings visibility</td>
<td>0: Very good; 0.25: Good; 0.5: Sufficient; 0.75: Unsatisfactory; 1: Poor</td>
</tr>
<tr>
<td><strong>Accessibility</strong></td>
<td></td>
</tr>
<tr>
<td>Dropped kerbs</td>
<td>0: Present; 1: Not present</td>
</tr>
<tr>
<td>Tactile paving</td>
<td>0: Present; 1: Not present</td>
</tr>
<tr>
<td>Audible signals</td>
<td>0: Present; 1: Not present</td>
</tr>
<tr>
<td>Presence of obstacles</td>
<td>0: Not present; 1: Present</td>
</tr>
<tr>
<td>Kerb width</td>
<td>0: kerb width$&gt;2$m; 1: kerb width$&lt;2$m</td>
</tr>
</tbody>
</table>
The prevalence is measured qualitatively using a semantic scale that links a numerical value (e.g. from 1 to 9) to a judgment expressing a possible result from the comparison.

A focus group of 15 experts, with previous experience in infrastructure design, road safety planning and evaluation, has been set up to perform pairwise comparisons. Each expert assessed the relative importance of criteria individually to avoid possible influence on judgments.

The weights of each criterion have been obtained aggregating the dominance coefficients of resulting comparison matrices through the geometric mean, obtaining the “aggregated comparison matrix”.

Results from the application of AHP method show that Night-time Visibility account for over 40% in both scenarios. Night-time Visibility resulted to have the higher weight in both scenarios (about 41%), followed by Day-time Visibility, Spatial and Temporal Design and Accessibility.

A composite index for crossing safety and indexes for each macro-criterion have been developed. For the determination of indexes, the following assumptions have been made:

- the safety level of a pedestrian crossing is calculated through a weighted mean;
- relationship among criteria has not been taken into account (i.e. combination of effects from two or more criteria has not been considered).

### 3.2. Methodology testing and application

Through the application of the methodology to a group of pedestrian crossings it is possible to order them by calculated safety level and get information both on pedestrian crossings that need to be redesigned and aspects that should be enhanced (through Macro and Micro-criteria indexes).

Two data gathering forms have been developed to collect information about signalized and not signalized pedestrian crossings. The forms include also two diagrams in order to guide the inspector in measuring main elements and visibility conditions. Required measurements are identified by letters (related codes present in the form are reported in parenthesis) and address to: a - Pedestrian crossing width (10.I); b - Distance between bus stop and crossing centre line (10.F); d - Distance between crossing centre line and nearest sight obstruction (10.B); l - Pedestrian island / median width (9.F); L - Crossing distance (10.D); o - Sight obstruction width (10.C).

A complete inspection is performed in two phases, with daylight and during night hours, and it takes about 30 minutes. Data collected can be input into a spreadsheet that performs all necessary calculations to get results about overall crossing safety and at macro-criteria level.

For testing purposes a sensitivity analysis to examine the criteria that have more relevance on the safety level determination has been carried out using data gathered for a group of pedestrian crossings of the city of Parma (Italy). The selected area belongs to the city centre, inside this area there is a public park, some important transport facilities and other points of interest. A group of 15 crossing was evaluated and the rankings considering Safety index and Macro-criterion indexes were elaborated. An analysis of changes of the ranking by removing a macro-criterion one by one was performed.

In the first column of Table 2, ranking by total safety level is reported, the other columns report ranking without “Spatial and temporal design”, “Day-time Visibility”, “Night-time Visibility” and “Accessibility” respectively. White cells point out an unchanged position compared to “Total Safety” ranking, light grey cells represent a shifting of one or two positions compared to “Total Safety” ranking while dark grey cells display a shifting of three or more positions compared to “Total Safety” ranking.
Within the project co-financed by FIA Foundation data from 215 pedestrian crossings across 17 European capitals have been collected.

All investigated pedestrian crossings have been selected from specific urban city areas. City areas are required to respect a number of aspects to guarantee a similar urban context. City areas selection takes into account: presence of at least a tourist point of interest (museums, churches, etc.), presence of important public transport facilities such as underground stations or main bus or tramway stops, presence of traffic critical points (school area, commercial area, roundabouts, etc.), not prevalence of pedestrian areas, a circle length of 2/3 kilometers.

Rankings of the 215 crossings by safety index and by macro-criteria indexes have been carried out.

For every investigated city a file with a summary of results has been developed. Analysis with proposed methodology highlighted some common issues present at European level such as: absence of pedestrian refuge islands, improper traffic light timing, car parking blocking visibility and frequent accessibility problems due to obstacles on pedestrian crossing.

Table 2 Changes to safety level ranking by removing macro-criteria

<table>
<thead>
<tr>
<th>Ranking by Safety level</th>
<th>Ranking Without &quot;Spatial and temporal design&quot;</th>
<th>Ranking Without &quot;Day-time Visibility&quot;</th>
<th>Ranking Without &quot;Night-time Visibility&quot;</th>
<th>Ranking Without &quot;Accessibility&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>A1</td>
<td>A1</td>
<td>A1</td>
<td>A1</td>
</tr>
<tr>
<td>A2</td>
<td>A4</td>
<td>A2</td>
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<td>A2</td>
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<tr>
<td>A3</td>
<td>A5</td>
<td>A3</td>
<td>A3</td>
<td>A3</td>
</tr>
<tr>
<td>A4</td>
<td>B1</td>
<td>A4</td>
<td>A4</td>
<td>A4</td>
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4. Review of the existing DSS's and their requirements

4.1. EU-project ROSEBUD

The EU-project ROSEBUD stands for “Road Safety and Environmental Benefit-Cost and Cost-Effectiveness Analysis for Use in Decision-Making”. In text below the key results of this project can be found:

• Safety effects estimated should satisfy the criteria of correct safety evaluation. A distribution of a brief guide on standardized techniques (like the above mentioned framework) for the evaluation of safety effects would be helpful for safety practitioners, in general, and particularly, for the improvement of quality of the efficiency assessment studies.

• Information about the implementation costs of safety measures is usually lacking. Establishing databases with typical implementation costs of safety improvements would be of help for the systematic use of these values in the efficiency assessment studies.

• A database with typical values of safety effects, based on the above mentioned handbook and other international experience would be useful for correct and systematic performance of the “ex-ante” studies.

• Consideration of a number of scenarios is useful for testing sensitivity of the results and should become common for the usual evaluation practices.

• For a more correct and uniform performance of cost-benefit analysis (CBA) for safety-related measures it would be useful to elaborate a categorization of cases, indicating the types of impacts (e.g. safety, mobility, noise, air pollution) to be considered in the evaluation of each category of measures.

• It is important to clarify the definitions of projects for which an assessment of safety impacts should be performed. It is suggested that the safety related efficiency assessment should be applied mostly for two types of projects:
  o improvements which were financed by safety-dedicated budgets and
  o projects aimed at improving safety.

Technical implications of results by theme

• When presenting efficiency assessment results, it is important to make a distinction between “technicians” (the professional level) and others. The language and the details should be adapted to the targeted population.

• Cost-benefit analysis seems to be more suitable for national- and regional-level decision-making where the safety budgets are planned. Cost-effectiveness analysis seems more suitable for local level, especially when several safety solutions are compared while tackling a specific safety problem.

• In the countries where the safety budget is centralized, an efficiency assessment of safety measures may be distributed by stating it as a necessary condition for the application to central budget.

• Training of decision – makers is important to strengthen their understanding of the principles of efficiency assessment.

Policy implications

• Efficiency assessment training should be introduced on an international level. Educational efforts at national level might be important, too, but they could be
ineffective, since the number of experts needed per country is rather low (especially in small countries).

- An international education initiative could, on the long run, contribute to harmonizing methods and procedures of efficiency assessment itself and the methods used for investigation and calculation of input data (e.g. unit values for different costs).
- A syllabus or curriculum for training of efficiency assessment experts should be developed.
- Based on this syllabus, a computer based multimedia training tool for experts should be developed, either on an internet platform or on digital media.
- The accessibility of data (e.g. about implementation costs) needs to be further improved. Internet platforms could serve as a basis to make such data easily available for all experts.
- Even the best training cannot cover all issues, therefore an internet forum should be raised to serve as a common information platform for questions occurring during a specific calculation or to discuss new problems, where no standard procedure is available to solve them. Experts should advise this forum. A FAQ section should cover topics, where solutions are developed, but not so far published.

The same internet platform could also be used to offer and co-ordinate quality assessment of efficiency assessment studies. Therefore, a board of evaluators of international reputation should be created. Quality checks should be offered within a predefined period by predefined costs. It would also be recommendable to create a common quality check label to be used for all evaluations carried out under this umbrella.

4.2. EU-project RIPCORD-ISEREST

4.2.1. Accident Prediction Model (SWOV)

An Accident Prediction Model (APM) is a mathematical formula describing the relation between the safety level of existing roads (i.e. crashes, victims, injured, fatalities etc.) and variables that explain this level (road length, width, traffic volume etc.).

Traffic volumes (vehicles per day) and road lengths (km) are the most important explanatory variables in an APM, both for road sections and intersections. The parameters of the model, however, can vary considerably between road types and countries. The reason is that road characteristics can differ considerably and so can road user behaviour, vehicle types etc. It is therefore recommended to make APMs per country and road type and use these to compare the safety level of a road against the value of the APM for the road type and traffic volume under consideration. APMs can thus also play an important role in identifying black spots.

4.2.2. Road Impact Assessment (SWOV)

A Road safety Impact Assessment (RIA) is a methodology to assess the impact of plans on safety. This can be major road works, a new bridge etc. that may or may not be intended to raise the safety level. A RIA can also concern a wider scheme i.e. be intended to make plans for the upgrading the safety level of a total network or area.

For a RIA on single (major) road works several methods are available. It is best to use as much scientific evidence as possible, using handbooks, cost-benefit analyses and taking into account network effects. For RIAs on wider schemes or even national levels specific recommendations are given on methodology. In general a RIA is best used in comparing policy options and setting ambitious but realistic road safety targets. Absolute numbers that
are predicted are usually not very reliable and in general highly dependant on high quality databases that are usually not available.

4.2.3. SEROES (INECO S.A.)

SEROES (secondary road expert system) is a web-based tool, freely accessible for everybody which comprises the possibility to be enlarged. In that context best practice information about road safety improvement from EU-member states and a worldwide background has been collected, examined and synthesized.

The application is structured into various menus for users and an additional menu for administrators. SEROES is a tool with low accident and road data requirements. The user only needs the accident site, accident type and the cause of the accident as input to describe an existing road safety problem. Then the application offers several solutions, a cost-range and information about the effect for each of the provided measures. For a better understanding a user manual has been developed.

4.2.4. Road Safety Performance Functions (TU-Dresden)

The improvement of road safety is an important challenge to infrastructure engineering. Various road safety procedures with different objectives and application fields have been developed in order to contribute to a further decline of especially accidents with fatalities.

On the one hand there are procedures which analyze the current situation and are often realized for and applied to road operation or are already integrated in the planning process. They are helpful tools for several users such as road engineers or road managers. On the other hand, accident prediction models and safety performance functions have been developed in order to estimate possible impacts of road infrastructure on road safety. The main difference is that they are based on mathematic models derived from scientific investigations and calculate statistically possible effects.

Accidents are influenced and caused by many various factors. The interaction between driver, vehicle and environment is complex and so far there is no model that considers all aspects of impacts. But numerous research studies have shown that beside properties of infrastructure also the behaviour of drivers has to be taken into account in order to analyze accident causes more accurately. Therefore, this tool considers both the impacts of road infrastructure parameters as well as the behaviour of drivers. This is achieved by the definition of section types that classify the existing horizontal alignment of roads based on driving behaviour models. A section is defined as stretch of certain length and it has almost constant impact on speed due to its geometric properties.

Investigations of accident structure have pointed out that especially single accidents like driving accidents and accidents in longitudinal direction like passing accidents or rear end collisions have the largest portion on the total number of fatalities on secondary rural roads. For that reason, the development of safety performance functions is based on investigation and evaluation of selected accident types which are connected to the alignment of roads.

For the geometric parameters curve radius, curvature change rate and furthermore, for speed differences between consecutive elements correlation models have been developed which calculate estimated accident rates and accident cost rates. Additionally, also the impacts of traffic volume and road width were considered. In order to evaluate the calculated results, a comparison to average accident rates and accident cost rates was suggested which shows possible safety potentials within the investigation area.

The derived results within the RIPCORD-ISEREST-project show that the investigation methodology is appropriate. Also the section definition and the pre-selection of accident types were approved since it lead to more accurate results and better correlation factors.
4.2.5. Decision Support Safety Tool (Mobycon)

The important objective of the RIPCORD-ISEREST project was to stimulate a safety oriented management of (secondary) road infrastructure. In order to achieve this, a practical tool has been developed to assist road managers and other decision makers on a regional level in finding the most appropriate way road safety intervention measures can be made. This practical management tool is called decision support safety tool (DST). This management tool is based on the VIB that was developed in 2003 and successfully applied in 7 regions in the Netherlands by Mobycon. The basis for the DST was the Road Safety Explorer by the SWOV in the Netherlands.

The DST is based on the relation between road safety (amount of deaths and hospital injured or accidents) and the amount of AADT (current situation and expected increase). This is called the risk: the amount of deaths and hospital injured (or accidents) per amount of traffic (AADT). The SWOV has described this as ‘the level of road safety is the product of the mobility of the road user and the risk of taking part in this mobility’. The DST predicts the number of deaths and hospital injured in a forecast year based on:

- The actual road, traffic and accident situation in a basis year.
- The expected increase of the AADT.
- The risk reductions by implementing road safety measures.

Within this project the DST has been tailor made for local circumstances in different EU-countries. The most important modifications to the DST are modifications with regards to the user-interface of the DST and the road safety measures (implementing own road safety measures by each country, the possibility to get more information about the measures, translation from English to another language, etc.) within the DST.

The information about road measures (costs and effects) is extracted from SEROES (see above). The costs and effects can of course differ per country, but when there is no information available in a country, this information can be used as a starting point. The overview of measures in the DST should be checked before working with the DST in a country by a team of experts from this country in order to create a sufficient and appropriate list of (potential) measures. Implementing new measures or adapting costs or effects can be done easily. The only restriction is that there should be information available about estimated costs and effects of measures.

The demonstration projects in this project pointed out that it is possible to work with the DST in different EU-countries despite a lack of digital data available. It is only strongly recommended to let the process be managed by an experienced institution or consulting company.

The Figure 36 below shows the position of the DST in relation to:

- Road-User Behaviour model.
- SEROES: safety expert system.
- Safety Performance Functions.
- Road Safety Handbook.
Figure 36: Position of DST in relation to other tools

The Figure above shows the different applications within the RIPCORD-ISEREST project in relation to the data need and applicability on local level. SEROES (safety expert system) and the Safety Handbook can be used without having a lot of data available. The tools are especially meant to give the user information about road safety and road safety measures and can be used on both a local and regional level.

The ‘road user behaviour model’ (not mentioned in this initial review), ‘safety performance functions’ and ‘DST’ need more data to be able to work with on a correct way. These tools are more appropriate for a regional level.

4.3. VVR-GIS 3.0 (SWOV)

The purpose of VVR-GIS 3.0 is to assist road authorities and policymakers in drawing up and substantiating traffic and transport plans. With VVR-GIS 3.0 it is possible to estimate the effects of regional and local road safety measures in different plans. These estimates can then be compared among themselves or with the targets. This can be the basis on which a region can determine whether a plan is feasible and whether it meets the regional target. As VVR-GIS 3.0 also performs a cost-benefit calculation, the user can determine which plan is most cost-effective.

VVR-GIS 3.0 consists of several parts. The user only sees the “user interface” – the maps, buttons and menus. The user can draw on a list of measures of which SWOV, based on scientific publications, has been able to determine the road safety effects.

The calculations are performed by the so-called ‘calculation kernel’. This calculation kernel makes use of all kinds of data, like information about growth scenarios for mobility; this data is stored in the ‘VVR Database’. Finally, the user interface retrieves information about the road network from an external database which contains road features (at present the application Wegkenmerken+ maintained by the Centre for Transport and Navigation). The underlying report discusses the calculation kernel in detail.

The calculation kernel performs its calculations in a number of steps which are briefly presented below.

The reference situation

The reference situation is the basis for the calculations. It describes the traffic and road safety situation of a region in a recent year of which traffic and road safety data is available.
The traffic situation in the reference year is expressed in vehicle kilometres for each category of road section and intersection in the region. The road safety situation in the reference year is established by:

- the real numbers of injury crashes, fatalities, and in-patients;
- the crash rate (number of injury crashes divided by the vehicle kilometres);
- two 'measures of severity': the number of casualties (fatalities and inpatients) per road crash and the proportion of fatalities among the casualties.

**The baseline prognosis**

A baseline prognosis for a year after the reference year gives the expected number of injury crashes, fatalities, and in-patients for that year if no local or regional measures from the list of measures available in VVR-GIS 3.0 were to be carried out. The baseline prognosis is based on two developments on which the VVR-GIS 3.0 user has no (direct) influence: the changes in mobility and the 'autonomous' change of the crash rate (for example as a result of measures taken on a national level).

**The measure prognosis**

After the baseline prognosis has been made for each year, the effects resulting from the application of measures from the list can be calculated. The results are called the measure prognoses. A measure prognosis is a forecast of the number of injury crashes, fatalities, and injury crashes in a year when the effects of the selected sets of measures are taken into account. The effects of applying the sets measures are calculated compared to the baseline prognoses. This means that the numbers of injury crashes, fatalities, and in-patients according to the baseline prognoses are multiplied by the reduction factors of the selected sets of measures.

**The effects of sets of measures**

The effects of sets of measures are expressed in the numbers injury crashes, fatalities, and in-patients saved. These are not the savings compared to the reference year, but the savings compared to the baseline prognosis. This way the numbers saved only show the effects of the used sets of measures and not the effects of all sorts of developments that the VVR-GIS 3.0 user cannot influence.

**The cost-benefit analysis**

A cost-benefit analysis makes clear whether the benefits of an investment counterbalance the costs from a social point of view. In addition to financial aspects, matters like safety, emission and congestion can also be taken into account. This way a cost-benefit analysis enables making pronouncements about the social profitability of an investment. Within VVR-GIS 3.0 a cost-benefit analysis is used to compare between different possible sets of measures. The costs in this analysis are the costs of the construction and maintenance of the sets of measures; the benefits are the crashes, fatalities, and in-patients that are saved as a result of the sets of measures. This comparison can support the user in making a final choice between the possible sets of measures.

VVR-GIS can only be applied successfully if sufficient data is available. These are mainly data of road sections and intersections. The present calculation method assumes the availability of this data in Wegkenmerken+ (for the Dutch situation), but for many regions the required data is not available in this application. Therefore, extra efforts to complement the Wegkenmerken+ data are strongly advisable.

Possible future developments concerning VVR-GIS are its extension with, for example, an environmental and/or mobility module. These calculate the effects of road safety measures on the environment and on mobility so that these effects can also be included in a cost-benefit analysis.
4.4. Risk Mapping and Star Rating (EURORAP)

Risk Mapping

An important aspect of EuroRAP’s work is to develop partnerships between road-user organizations and road providers, and to produce results that will be meaningful to the motoring public, policy-makers, highway providers and operators alike.

Maps make it easy to identify the safest and most dangerous road sections within a region or country and, by comparing maps for different countries, enable European comparisons of safety performance.

In recognizing that the view of safety differs between stakeholders, depending on their role in achieving a safe highway network, EuroRAP maps give various insights into risk and can be used to support messages aimed at the differing needs and levels of expertise of the target audiences. Under EuroRAP’s Risk Mapping protocol, safety indicators based on the road network, accident numbers and traffic flow can be used to produce four maps:

- Risk per kilometre
- Risk per vehicle kilometre travelled
- Risk in relation to roads with similar flow levels
- Economic potential for accident reduction

A typical EuroRAP road section is 20 kilometres long with 20 deaths and serious injuries in just 3 years as much as a major rail crash. However, this target can be modified as necessary to ensure that links of roads selected are meaningful and distinct to road-users (for example start and end at identifiable locations) and have broadly similar characteristics along their entire length (such as single lane or dual carriageway). Some short sections of road (e.g. link roads), and some that carry low traffic volumes are inevitable in the sample. These short sections (e.g. less than 5km), those that have small accident totals (e.g. less than 7), or carry low traffic volumes (e.g. less than 3,000 per day) are more likely than others to experience greater year-to-year variation in accident rate and are therefore more likely to change risk rating from one period to another.

Using EuroRAP’s Risk Mapping protocol, road sections are colour-coded according to five risk bandings indicating their level of accident risk:

- Low
- Low-Medium
- Medium
- Medium-High
- High

Due to differences in the definition and reporting of fatal and serious accidents across Europe the raw data collated for each country is adjusted to allow comparisons of relative safety risk.

To bring the data in line to a European norm, different thresholds for each risk rate banding (low, low-medium, medium, medium-high, high) are used. This adjustment is based on the ratio of the number of fatal accidents to the number of accident type (for example, fatal and serious, or all injury) collected for that country.

The aim of this adjustment is not to change one country’s accident reporting practice to fit that of another, nor is it to artificially increase or reduce rates in any country. The adjustment
simply gives a better estimate of relative long term accident rate for each link within a national network.

Where material included on the site has not been subject to this adjustment, and therefore, where it cannot be compared directly with other countries, this is clearly marked.

**Star Rating**

The Road Protection Score (RPS) is a scale for Star Rating roads for how well they protect the user from death or disabling injury when a crash occurs. The aim of the assessment is to evaluate the safety that is ‘built in’ to the road through its design, in combination with the way traffic is managed on it.

Data on road design and the standard of a road’s safety feature is collected by drive-through inspections in specially equipped vehicles. Trained inspectors assess and score each road’s safety features and hazards, either in real time (as the road is driven), or later from video images captured along the route. This standard inspection formula can be used on a variety of road types and allows roads across Europe to be assessed and compared on the same basis. EuroRAP’s Star Rating differs from normal road safety audits as the aim is to assess the general standard of a route and not identify individual black spots.

The RPS is a new scale which will be continuously improved as the evidence builds – the current path finding programme of road inspections and Star Rating already includes 8 countries globally.

Road authorities across Europe currently have different views about the technical importance of a road’s Star Rating. In several countries, authorities and motoring organisations are engaged in significant research and discussion on road protection standards and their relationship to speed limits or road engineering standards.

The Star Rating tends to be regarded as more important in countries and regions where accidents are sparse and patterns random. In these countries the location of the last accident is no guide to the next, one unprotected tree out of hundreds is no more likely to be struck than any other. But in other countries accidents are regrettably so frequent that the information from accident records and site studies alone allows identification of priorities and the treatment needed.

As the evidence base grows, the relative contribution of EuroRAP’s protocols in helping generate priorities and countermeasures in different circumstances will become clear. Whatever the immediate priorities for action, in future, road design and layout should neither invite human mistakes nor allow the consequences of a mistake to be fatal. Safe roads mean roads that are both “self-explaining” and “forgiving”.

### 4.5. EUSKA (PTV – Germany)

Today, most of the police authorities in Germany rely on the road accident analysis system EUSka that allows them to geo-reference all accident data on a digital road map and to instantly analyse the information by means of the powerful database.

The police authorities used to store the accident data locally. EUSka’s central server solution contributes significantly to the improvement of road safety by providing data that can be used by all staff members of the authority to enhance road safety throughout the different states.

**EUSKA – Methodology and system architecture**

An explanatory leaflet about recording and analysing road accident on maps explains how to analyse road accident data in Germany. This includes the classification of accident data and the analysis procedures for local accident investigations. EUSka was developed according to these requirements.
Digital maps
The exact location is a decisive factor for accident data. Therefore, PTV has provided two options for data entry on the map, either by integrating a localisation module into an external records management system (the separate module automatically presents the map, computes the coordinate after a mouse click and transmits the information to the records management system), or by using a complete data completion module for post-localisation within EUSka. EUSka uses PTV maps.

Additionally, it is possible to provide the authorities' maps with the help of so-called WMS services and to integrate the data in the form of several layers.

Analysis options
The system provides numerous data analysis options. A particular emphasis is placed on the accident analysis maps used by the police in Germany. They display the accidents on a road map over a period of 12 months or on maps covering a period of three years to record road accidents with fatalities and injuries which normally occur less frequently and often on other road sections than the accidents without injuries. The data is used for local accident investigation in order to identify obvious similarities in accidents in a black spot.

The geo-referenced accident database provides additional analysis options that go far beyond conventional accident analysis mapping.

Numerous search options
Numerous search functions are particularly helpful. All search results can be directly displayed on additional maps on the screen. It is also possible to systematically search for patterns in the number and type of accidents and in problem sites. The accident data can be filtered according to almost any accident criteria: for example, all accidents occurring inside urban regions, involving cyclists and children between 6 and 14 years of age. Specific periods of time, such as school start times, or areas like school zones can also be included in the investigation. Additionally, there are unlimited possibilities to search for data on accidents occurring outside urban areas. Users can thus easily find details of all accidents caused by excessive speed, alcohol or drugs, depending on the age of the people involved in the accident and the time and date. The new method therefore promotes road safety and helps change driver behaviour by implementing specific traffic control measures.

Quality control and cooperation
This analysis technique sets a new quality standard. It creates a solid, verified database, using standardised digital maps and data that can be transmitted electronically to other authorities involved in road safety work. High-quality road accident data is essentially based on two components: digital maps and plausibility checks.

Analysis of black spots
To avoid road accidents it is essential to analyse the accident black sports, which is a fundamental task of the accident committee. The so-called automatic search for black spots quickly and efficiently analyses the entire area by scanning parameterised squares. If the pre-defined limit values are reached, the accident black spots are directly visualised and can easily be used for further analysis. The local distribution of accidents is a decisive factor in order to find the locations where accidents often occur. The distribution might vary as it depends on the course of the route or the size of the intersection area. For each automatic search process the map section and the size of the basic square can therefore be defined very flexibly according to the type of accident. The key figures and results can be calculated and listed for all accident black spots detected by the system. The automatic prioritisation helps the police to quickly rank dangerous accident black spots and to analyse them accordingly.
EUSka automatically generates the lists required for the analysis. Soaring black spots can easily be identified by means of the time graph. The time graph also helps to analyse the impact of the measures taken to reduce the accident rate.

Visualising, analysing, taking measures

The local accident investigation results will have to be analysed on the basis of accident prevention concepts developed for these accident black spots. These concepts have to be adjusted to the specific local requirements in order to be able to take concrete measures and tackle the problem at that location. To this end, all parties involved will work out an action plan based on these remedial measures.

4.6. Road Safety Toolkit (IRAP)

The Road Safety Toolkit provides free information on the causes and prevention of road crashes that cause death and injury. Building on decades of road safety research, the Toolkit helps engineers, planners and policy makers develop safety plans for car occupants, motorcyclists, pedestrians, bicyclists, heavy vehicle occupants and public transport users.

The Road Safety Toolkit is the result of collaboration between the International Road Assessment Programme (iRAP), the Global Transport Knowledge Partnership (gTKP) and the World Bank Global Road Safety Facility. ARRB Group provided expert advice during the Toolkit’s development.

More information: http://toolkit.irap.org/default.asp

4.7. Pedestrian&Cyclists analysis (I.T. Ingegneria dei Trasporti Srl, Italy)

The tool allows to find possible interventions to improve safety of VRUs; it is possible to have disaggregate or aggregate approaches based on data availability and reliability; moreover it allows to estimate effectiveness of interventions and provide main output in form of a report

Pedestrian & Cyclist Analysis (PCA)

- PCA is an additional tool of SFINGE focused on VRU accident analysis (extra datasheet was needed).
- PCA guides the user to find appropriate countermeasures on the basis of the accident pattern and location characteristics.

PCA Basis

- PCA was developed to support the Municipality of Parma in specialized analysis of VRU’s accident data.
- Designed in partnership with CTL acquires the results of international experience and research activities. The knowledge base has been validated according to the Italian context.

PCA Accident Database

- PCA uses accidents data recorded by the Police with the SFINGE32-modules:
  - Data collection (on site).
  - Data management (in office).
- Accidents are fully featured and geo-referenced.
- An extra dataset focused on accidents involving VRU’s is collected.

32 SFINGE is a software, developed by IT, for accidents on-site surveys, and further analyses and management; data are automatically collected (by computer, cameras, GPS positioning) on the spot and then stored to create a database.
PCA Crash-Pattern

- A code that identifies an accident schema based on:
  - Vehicle manoeuvres: e.g. vehicle in reverse on a private access, ...
  - Pedestrian actions: e.g. walking/running in the same direction, leaving/entering other vehicle, ...
  - Cyclists actions: e.g. turning right / left, down from sidewalk, ...
  - Accident circumstances: e.g. on crosswalk, traffic light changes, ...

PCA step-by-step analysis process (see also figure below)

- Pedestrian or Cyclist accidents analysis.
- Accidents classification by CP in whole area (aggregated) or element by element (disaggregated).
- Accidents analysis by location: links or junctions.
- Representation of possible causes, related countermeasures and expected crash reduction factors.

![PCA Crash-Pattern](image)

Figure 37: Sfinge PCA UI

This DSS has four main functions:

1. Analyse accidents main factors, trends, black spots to plan sound strategies.
2. Find out the more appropriate solutions for the addressed critical issues, under the economic point of view.
3. Assess improvements/failures due to traffic management or infrastructural interventions.
4. Assess the efficiency of selected interventions.

ISIDE provides also a continuously updated database and a GIS module for the geo-referenced data treatment.

A core task is the possibility to perform RIAs, thanks to traffic simulation models and accidents forecasting models which allow, according to the surveyed traffic flows (Safety Performance Functions), to assess the general impacts due to the chosen interventions on the safety levels not only on the links where such measures are applied, but also in the links nearby.

ISIDE fully complies with the following actions foreseen within the EC Directive 2008/96:

- Data management.
• Road Safety Impact Assessment.
• Safety ranking and management of the road network in operation.

4.9. PBCAT – Pedestrian and Bicyclist Crash Analysis Tool (FHWA)

PBCAT is a software application meant to assist state and local pedestrian and bicycle coordinators, planners, and engineers in addressing pedestrian and bicyclist crash problems by allowing them to enter and analyze crash data.

What is PBCAT?

In 2004, 4,641 pedestrians and 725 bicyclists were killed in traffic crashes, accounting for more than 12 percent of all traffic fatalities in the United States. An additional 68,000 pedestrians and 41,000 bicyclists were reported to be injured as a result of incidents involving motor vehicles. PBCAT is a software application designed to assist State and local pedestrian and bicycle coordinators, planners, and engineers in addressing pedestrian and bicyclist crash problems.

PBCAT accomplishes this goal by enabling users to develop a database of details associated with crashes between motor vehicles and pedestrians or bicyclists. One of these details is crash type, which describes the pre-crash actions of the involved parties. After developing a database of crash information, PBCAT users can analyze the data, produce reports, and select countermeasures to address the problems identified by the software.

Why Crash Typing?

Computerized State crash files that contain insufficient details about the crashes hinder the development of effective countermeasures to prevent bicyclist and pedestrian crashes. Analysis of these files often provides data that includes where pedestrian and bicyclist crashes occur, such as the city, street, type of street, or intersection; when crashes occur, such as the time of day or day of the week; and the characteristics of the victims, such as their age, gender, and severity of injuries. These data, however, do not provide adequate detail to determine the sequence of events that lead up to and cause crashes.

During the 1970s, the National Highway Traffic Safety Administration developed methodologies for typing pedestrian and bicycle crashes to better define the sequence of events and precipitating actions leading to crashes. In the 1990s, the methodologies were applied to more than 8,000 pedestrian and bicycle crashes in six States. The results provided a representative summary of the distribution of crash types experienced by pedestrians and bicyclists. Over time, this method has evolved and was refined during development of PBCAT.

PBCAT features

PBCAT latest version has an enhanced design that makes the software easy to use. In particular, it operates in a very common environment, with easy-to-use pull-down menus and toolbars. Users can customize the form for inputting crash data and design it to match the police crash reports used in their community.
It is possible to record specific location information, such as approach and travel direction, for pedestrian crashes occurring at intersections. Results and data may be exportable to spreadsheets for further customization.

PBCAT provides users with access to detailed descriptions of engineering, education, and enforcement countermeasures that address specific types of crashes. Each countermeasure description includes a purpose, considerations, estimated cost, and real-world case studies.

More information: http://www.bicyclinginfo.org/facts/pbcat/about.cfm

4.10.PEDSAFE – Pedestrian Safety Guide and Countermeasure Selection System (US Department of Transportation – FHWA)

PBCAT is linked also to other two safety tools, the Web-based Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE) and the Bicycle Countermeasure Selection System (BIKESAFE), which will be described in the next section; moreover, PBCAT information can be integrated with the Road Safety Audit process provided by the

Pedsafe is an on-line, expert system which provides the user with a list of possible engineering, education, or enforcement treatments to improve pedestrian safety and/or mobility based on user input about a specific location. The core of PEDSAFE is represented by the following on-line tools:

a) Selection Tool – which allows the user to develop a list of possible countermeasures on the basis of site characteristics, such as geometric features and operating conditions, and the type of safety problem or desired behavioral change. The Selection Tool has three steps:

1) Choose the location (i.e. to enter the site location, for instance: junction);

![Figure 41: PEDSAFE location choosing](image)

2) Select the Goal of the Treatment which can be referred either to a given performance objective to achieve (for instance “reduce traffic volume”) or an action to mitigate a specific type of pedestrian/motorised mode collision;

![Figure 42: PEDSAFE goal selection](image)

3) Describe the site: this step (according to the goal selected in the previous step) provides answers to an on-line questionnaire concerning the geometric and operational characteristics of the site. The answers to such questions are used to narrow the list of appropriate countermeasures for the selected goal.

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\(^3\)The Pedestrian Road Safety Audit Guidelines and Prompt Lists is a traditional reference book aimed at providing multidisciplinary teams (transportation agencies and practitioners) with a better knowledge of pedestrians needs, when conducting a Road safety Audit (RSA). In particular, such Guidelines have two sections: the “Knowledge Base” (i.e. the basic concepts with which the RSA team should be familiar before conducting an RSA) and the “Field Manual” section with detailed descriptions of potential pedestrian safety issues, along with a series of prompt lists, i.e. a general listing of potential pedestrian safety issues.
b) Interactive Matrices (objectives/countermeasures matrix + crash groups/countermeasures matrix) – to assess the relationship between the countermeasures and the performance objectives or crash types, previously selected. In particular, for the former, the user may choose between 8 performance objectives and the 7 countermeasure groups and for the latter a similar choice between the 12 crash type groups and the 7 countermeasure groups.

In both the matrices, any filled cell indicates that there is a specific countermeasure within the countermeasure group that is applicable to the crash group or performance objective listed in each row. By clicking on the bullet in any of such cells it is possible to have a list of the 49 applicable countermeasures, duly detailed. Such countermeasures are divided into several education and enforcement treatments or programs, according to the following categories: pedestrian facility design, roadway design, intersection design, traffic calming, traffic management, signals and signs, and other measures.

A set of 70 case studies is also provided to describe suitable solutions implemented in a given state/municipality.

More information: http://www.walkinginfo.org/pedsafe/
4.11. BIKESAFE – Bicycle Countermeasure Selection System (US Department of Transportation – FHWA)

This is the PEDSAFE corresponding tool for those who bicycle; as PEDSAFE, BIKESAFE provides planners and designers with information available for improving safety and mobility by bike, and similar on-line tools as:

- the Selection Tool, based on the three-steps process: 1) Choose the location; 2) Select the Goal of the Treatment; 3) Describe the site
- the two Interactive Matrices (objectives/countermeasures matrix + crash groups/countermeasures matrix)

and it includes a detailed list of countermeasures and 50 case studies.

More information: http://www.bicyclinginfo.org/bikesafe

4.12. IHSDM (FHWA)

The Interactive Highway Safety Design Model (IHSDM) is a suite of software analysis tools for evaluating safety and operational effects of geometric design decisions on highways. IHSDM is a decision-support tool. It checks existing or proposed highway designs against relevant design policy values and provides estimates of a design’s expected safety and operational performance. IHSDM results support decision making in the highway design process. Intended users include highway project managers, designers, and traffic and safety reviewers in State and local highway agencies and engineering consulting firms.


4.13. Accident predictive models (Department for Transport (UK))

The Accident Predictive Models have been produced for all the main components of an urban road network including roundabouts, mini-roundabouts, traffic signals, major/minor priority junctions and the road links between them. The models estimate the number of accidents that can be expected, on average, given information about the flow of traffic and pedestrians and the design of the junction or link.

Models have been developed at a number of different “levels” with different input requirements. The most basic levels need simple traffic inflows averaged over the whole day. More detailed levels require additional information such as turning flows for traffic, pedestrian flows, and broad descriptions of major features such as the presence of islands and pedestrian facilities. The highest levels require detailed information about the geometric design of the junction or link and other information such as land use, and proportions of different vehicle types.

Depending on the amount of detail supplied, the models may be used to predict:

- the total numbers of accidents at a location
- vehicle and pedestrian accidents separately
- accidents of specific types – for example ‘right turn from minor arm’, ‘rear shunts’, ‘pedestrians crossing major arm’
The models within SafeNET take appropriate account of the flow of pedestrians, cyclists and motorcyclists in the calculation of the overall number of accidents likely to occur. In addition, SafeNET can separately estimate the number of accidents that would involve pedestrians. Results of this type are already produced by ARCADY, PICADY and OSCADY, but these programs are only suitable for indicating the performance of individual elements of a road network.

4.14. Road Safety Audit Interactive Checklist34 (Lancspartners)

The aim of this facility is to provide an interactive medium where practicing Road Safety Auditors can share information and experience of safety concerns identified whilst carrying out Road Safety Audits. The website comprises

- Customised Safety Audit Checklists for each stage of audit,
- Typical collision types for each scheme type initially generated from national casualty data
- Suggested document lists for each stage of audit
- A feedback facility for auditors to add/amend checklist comments/collision types
- Useful links to other relevant Road Safety Audit sites

The checklists are based on actual comments made by auditors in over 6000 audit reports over a 20 years period. They are not exhaustive and Road Safety Auditors will need to fully consider the safety aspects of the scheme being audited and include any other concerns in their Safety Audit Report.

4.15. Road Restraint Risk Assessment Process

Road Restraint Risk Assessment Process (RRRAP – Highways Agency, 2007) is an Excel-based model used by road designers in the UK to establish the need for a vehicle restraint (safety barrier or similar) at a scheme/site (normally trunk roads), and if necessary, its performance requirements. The RRRAP (Highways Agency, 2007) is designed to be used alongside TD19/06 (Highways Agency, 2006), which contains the mandatory requirements and also advice and guidance. The figure below gives an overview of the RRRAP process. The data is updated as required to ensure up-to-date costing information is used in the calculations made.

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Similar tools are the Road Safety Audit Toolkit, by ARRB Group (Australia) and the FHWA Road Safety Audit Software (USA).

The Road Safety Audit (RSA) Toolkit is an online tool that assists practitioners to carry out road safety audits. It steps users through the Austroads Road Safety Audit process (i.e. Feasibility stage, Preliminary design stage, Detail design stage, Pre-opening stage, Roadwork traffic scheme and Existing roads), provides Australasian and jurisdiction specific references, and allows auditors to generate road safety reports. The Road Safety Audit Toolkit is based on the Austroads Road Safety Audit Guide, 2nd Edition (2002). The software is free for Australian and New Zealand road safety professionals (username and password required).

The FHWA Road Safety Audit Software was developed to address these challenges and to support the practical implementation of the FHWA RSA Guidelines. It is intended to be a guiding and process tracking tool enabling the use of RSA prompt lists at variety of detail levels, while providing a way to accompany each safety issue raised with a discussion and assessment.
RRRAP allocates an ‘aggressiveness value’ to hazards close to the road, and estimates the number of fatalities per vehicle kilometre in order to calculate a risk value, and quantifies risk, likelihood and consequences of accidents with and without restraints in place. Risks are categorised as acceptable, tolerable, or unacceptable. The designer can then use this information to decide what sort of road restraint to use, the size and location of the restraint, until an acceptable level of risk is obtained.

4.16. Other Supporting Tools

Safety is an important facet of the road construction sector; consequently, some DSSs for managing roads and highways, especially developed for practitioners, road agencies, contractors, consultants and financial institutions, consider safety either as an externality or as a more general economic factor behind the building/management of a given road. Therefore, it is worth mentioning the HDM-4 Road Software Tool, developed under the aegis of the World Bank for Emerging Economies and Developing Countries.

4.16.1. HDM-4 Road User Costs Model (HDM-4 RUC)

This is an Excel based model designed to compute, for twelve vehicle types and different road conditions, vehicle speeds, fuel consumption, vehicle operating costs, passenger time costs, emission and accident costs based on the Highway Development and Management Model (HDM-4) relationships. The model computes unit road user costs, performs sensitivity analysis, computes network road user costs and performs a simplified economic evaluation of a road project.
The model estimates road safety costs of fatal and injury accidents, according to the iRAP methodology, whose main steps are:

- User defines vehicle fleet fatality rate in number, per 100 million vkm
- User defines vehicle fleet serious injury rate, per 100 million vkm
- Cost per fatality computed function of GDP per capita (default: GDP per capita multiplied by 70)
- Cost per serious injury computed function of GDP per fatality (default: 25% of fatality cost)

Developing Countries have been using the HDM-4 model since its release in 2000 for project or network level economic evaluations. For what concerns rural roads, a similar tool is available: Roads Economic Decision Model (RED). RED, developed to improve the decision-making process for the development and maintenance of rural roads, computes benefits for normal, generated, induced, and diverted traffic, and takes into account changes in road length, condition, geometry, type, accidents, and days per year when the passage of vehicles is further disrupted by a highly deteriorated road condition.


4.17. Conclusions

The Table 3 below gives an (first) overview of data need for using the DSS and the applicability of the DSS on a local or regional level per DSS (description on a qualitative way).

This classification for the data need and applicability on local level earlier has also been used in the EU-project RIPCORD-ISEREST. In the text below you can find some considerations for this division:

Data need:

From a starting point you need data to work with the DSS’s:

- Accident data on paper (low data need).
• GIS-data about the road network and accident data (including a database behind the GIS-data; middle data need).
• Information about roads and intersections and their environment in GIS (high data need).

Applicability on local level:
The applicability on local level is based on:
• The relevancy of the information on local level (e.g. the output).
• The average knowledge of road managers at local level about e.g. road safety and accident analysis. Are they able to understand the mathematical models behind the DSS and can they understand/interpret the results of working with the DSS?

<table>
<thead>
<tr>
<th>DSS name</th>
<th>Data need (low / high amount of data)</th>
<th>Applicability on local level (low / medium / high)</th>
</tr>
</thead>
<tbody>
<tr>
<td>APM</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>RIA</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>SEROES</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>RSPF</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>DSST</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>VVR-GIS 3.0</td>
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<td>High</td>
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<tr>
<td>Risk Mapping</td>
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<tr>
<td>Star Rating</td>
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<td>Medium</td>
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<tr>
<td>EUSKA</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Road Safety Toolkit</td>
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<td>PCA</td>
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<td>High</td>
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<tr>
<td>IHSDM</td>
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<td>High</td>
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<tr>
<td>RRRSP</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Accident Predictive Models</td>
<td>Low / High (different levels)</td>
<td>High</td>
</tr>
<tr>
<td>Road Safety Audit Interactive Checklist</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>
5. Conclusions

This deliverable has described the results of the review about international experiences, practices and existing Decision Support Systems that could be used as basis for the development of the tool of SaferBrain.

The topics reviewed mainly related with European experiences and tools that could be adapted to specific situations in Emerging Economies (in particular in India and Brazil).

During the report no comparisons were made between European experiences and situations in Emerging Economies. This aspect will be treated in WP3 basing on the outcomes of WP1 and WP2 and especially using the Transferability Audit developed in WP2. The results of these transferability / adaptability analysis will then be reported in another deliverable (D3.5) together with the results of the transferability / adaptability analysis of topics reviewed in D3.2.
References


Recommended Web Resources

http://www.ada.gov/reg3a.html#Anchor-Appendix-52467

http://archived.ccc.govt.nz/programmes/livingstreets/

http://en.wikipedia.org/wiki/Pedestrian_zone

http://en.wikipedia.org/wiki/School_zone

http://www.accesscode.info/external/5_12.htm


http://www.bicyclinginfo.org/facts/pbcat/about.cfm

http://www.bikeability.org.uk/

http://www.bikexpert.com/bikepol/facil LANES/CONTRAFLOW.htm

http://www.bta4bikes.org/at_work/bikeboulevards.php

http://www.ci.berkeley.ca.us/ContentDisplay.aspx?id=6650

http://www.ci.berkeley.ca.us/ContentDisplay.aspx?id=6652

http://www.ecf.com/14_1

http://www.guidedogs.org.uk/sharedstreets/


http://www.homezones.org/homeUK.html

http://www.ibpi.usp.pdx.edu/media/BicycleBoulevardGuidebook.pdf

http://www.kentwalkingbus.org/

http://www.kerbcraft.org/

http://www.leics.gov.uk/index/highways/road_safety/school_travel_plans/walking_bus_scheme.htm

http://www.livingstreets.org.uk/
http://www.parkandride.net/

http://www.rosace-europe.net/

http://www.saferoutesinfo.org/

http://www.shared-space.org

http://www.streetfilms.org/bicycle-boulevards4nyc/

http://www.streetfilms.org/the-capitols-colossal-contraflow-cycle-track/

http://www.streetsblog.org/2006/10/31/street-films-portland-week-bicycle-boulevards/

http://www.streetsblog.org/2007/01/24/streetfilms-berkeleys-bike-boulevards/

http://www.sustrans.org.uk/what-we-do/liveable-neighbourhoods/diy-streets/current-diy-streets-projects

http://www.sustrans.org.uk/what-we-do/national-cycle-network

http://www.thenationalbyway.org/welcome.asp


http://www.walkinginfo.org/library/details.cfm?id=3955

http://www.walkingschoolbus.org/

http://go.worldbank.org/FF0CT8M770