Chapter 2
Towards Forgiving and Self-Explanatory Roads

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2.1 The Concept of Sustainable Safety

"Sustainable Safety" is a road safety concept, by which the entire traffic and transport system is adapted to human limitations. The aim is to prevent crashes and to limit their consequences. The infrastructure prevents road use involving large differences in direction, speed and mass, and directs the road user towards safe behaviour. Vehicles are constructed to simplify the driving task and offer protection in the event of a crash. Road users are educated and informed properly and their behaviour is tested regularly. The essence of the Sustainable Safety approach is: prevention is better than curement (IN-SAFETY DoW 2005). The Sustainable Safety vision of road safety is based on five principles. These five principles refer to the functionality of roads, the homogeneity of mass and/or speed and direction, physical and social forgivingness, recognition and predictability of roads and behaviour, and state awareness. The following points are the goals of the Sustainable Safety vision (Wegman and Aarts 2006; SWOV 2007):

- The prevention of (serious) crashes, and where this is not possible, the almost total elimination of the risk of severe injury.
- The notion that man is the measure of all things due to his/her physical vulnerability and cognitive capabilities and limitations (such as fallibility and offence behaviour).
- An integrated approach to the elements human-vehicle-road, which is tuned to the human measure.
- A proactive approach to bridging gaps in the traffic system.

More specifically, the principles of sustainable safety can be summarized in the following table (Table 2.1):

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Table 2.1 Description of the five sustainable safety principles (Wegman and Aarts 2006)

Sustainable safety principle	Description
Functionality of roads	Mono-functionality of roads as either through roads, distributor roads, or access roads in a hierarchically structured road network
Homogeneity of roads	Equality of speed, direction and mass at moderate and high speeds
Forgivingness of the environment and of road users	Injury limitation through a forgiving road environment and anticipation of road user behaviour
Predictability of road course and road user behaviour by a recognisable road design	Road environment and road user behaviour that support road user expectations through consistency and continuity of road design
State awareness by the road user	Ability to assess one's capacity to handle the driving task

As seen in the table above, two of the principles are referring to forgiving and self-explanatory road environments. Thus, striving to define the road environment of the future, these two characteristics should be secured. According to FEHRL (2001), the roads of the future will need to:

- Contribute to sustainability.
- Make wide use of innovation.
- Contribute to improvements in road safety, environment and road transport efficiency.
- Reduce to zero any contribution to accidents ("forgiving road infrastructure").
- Reduce traffic congestion.
- Reduce noise and vibration to the road environment.
- Reduce air and visual pollution.

To achieve the forgivingness and self-explainability of road environments, the EC has committed researchers and other related stakeholders, by means of research initiatives, so that such environments would be defined and further described, along with the pre-requisites for a road environment to be characterised as such, both in term of infrastructure based measures and the use of new technologies.

2.2 Forgiving Road Environments

Forgiving road environments constitute a basic tool in preventing or mitigating an important percentage of road accidents related to driving errors. As everybody makes mistakes, drivers will eventually keep doing erroneous manoeuvres or actions. Over 80% of accidents are related to driver's error. More specifically, statistics show that about 25–30% of fatal accidents involve crashes with fixed roadside objects. Those accidents are mainly caused due to driving errors that lead to lane/road departure. The existence of a forgiving road environment would have prevented accidents of this type (and generally accidents that involve driving errors) and/or reduced the seriousness of the consequences of such accidents.

Forgiving road environments may also take advantage of advanced telematic and in-vehicle systems, which will support the driver in case of an error. Those systems, in contrast to traditional and autonomous ADAS (Advanced Driver Assistance Systems), will not only support the driver by providing an adequate warning, but will supplement the road infrastructure. This, for example, can be achieved by simulating a rumble strips sound or using other haptic warnings, when the driver involuntarily crosses the road marking, overspeeds or initiates an erroneous overtaking.

2.2.1 Definition

In the context of this book, a forgiving road is defined as a road that is designed and built in such a way as to interfere with or block the development of driving errors and to avoid or mitigate negative consequences of driving errors, allowing the driver to regain control and either stop or return to the travel lane without injury or damage.

Examples are roads that have structural layout elements that reduce the consequences of accidents or driving errors (e.g. when leaving the lane unintentionally) once they happen, or in-vehicle devices with the same function, like "Lane Departure Warning Assistant".

To develop a forgiving road environment certain characteristics must be included and measures should be taken, involving either the infrastructure itself or the use of telematic and other aids. Most notably, the combination of infrastructure and telematics measures can provide a more cost-efficient solution, as expensive infrastructure works may be substituted by telematics or other innovative systems.

2.2.2 Forgiving Road Environments in Practice

Devising the measures for forgiving road environments (FOR), as they by definition aim at avoiding or mitigating negative consequences of driving errors, starts with listing possible driving errors to be supported, that in turn are related to accident statistics. As various driving errors can be distinguished, usually some clustering or categorisation of errors is used. This procedure has been undertaken within the IN-SAFETY project (Wiethoff et al. 2006), where four levels of driving errors have been identified and relevant measures have been proposed for each error category:

1. Accident type errors: result of the execution of an error (e.g. collide with other vehicle).

Table 2.2 Errors and measures for FOR and SER measures

Measure error/scenario	In-vehicle	Infrastructure	Co-operative (based on vehicle-infrastructure and vehicle-to-vehicle communication and cooperation)
Speeding in an unexpected bend on rural roads	*Navigational aid*	*Variable message sign (VMS)*	*Electronic beacons, providing in-car info, merged into on-board navigation*
Over-speeding (in general)	*Speed alert system by speed sign recognition*	*VDS*	*Speed alert, based on digital maps, updated by road beacons*
Wrong use of road	*Lane departure warning system*	*Audio lane warning delineation*	*Adaptive LDWS*
Violation of priority rules	In-vehicle traffic sign recognition	Electronic traffic signs	*Traffic light status emitted to the car*
Overtaking failure	*Blind spot detector*	Rumble strips	Vehicle-to-vehicle communication
Insufficient safety distance	*A frontal warning system*	VMS with fog warning	*Adaptive frontal warning systems*

2. Driving errors: action that leads to an accident (e.g. inappropriate speed).
3. Human error: psychological process that forms the basis of a driving error (e.g. incorrect evaluation of speed and distance).
4. Psycho-physiological condition: condition that can influence the underlying psychological process (e.g. fatigue).

The safety potential of each measure has been estimated, followed by the construction of relevant scenarios (see Table 2.2) and their consecutive prioritisation, using the MCA/AHP methodology (more on these issues can be found in Chaps. 3 and 16).

2.3 Self-Explanatory Road Environments

The other basic principle of sustainable safety that is discussed in the present is this of self-explanatory roads (also referred to as self-explanatory roads). What this term implies is the interaction between the infrastructure (including the road, the road equipment and the whole roadside environment) and the road users. The key issue in this case is that the road succeeds (either by its layout, or by adequate signing) to communicate correctly to its users the necessary "messages", so that they would be able to use it effectively, in the least distracting and risk-generating manner.

Examples are consistent pictograms and/or earcons, which are used in the traffic environment as well as employed by in-vehicle applications, to inform the driver or warn/alarm him/her upon the direction to follow, regarding danger ahead, etc. The multi-ethnic character of modern societies and the effects of globalization on the road network make it all the more important to substitute text at VMSes and on-board systems with internationally recognized symbols and sounds, many of which correspond to new functions (such as traffic congestions level, navigation, route guidance, lane deviation/departure, distance from frontal car, overspeeding, traffic management control signals, etc.) and thus are not included into the signs of the Vienna Convention.

But self-explanatory roads measures are not limited to standardization of the interaction elements because, no matter how standardized they become, they are still surely not suitable for everybody. Thus, a key element is that of information redundancy but also consistency and timeliness of provision and, ultimately, on info and warning adaptation and personalization, to match the individual participants own needs (Bekiaris et al. 2005).

2.3.1 Definition

In the context of this book, self-explanatory road is defined as one that is designed and constructed to evoke correct expectations from road users and elicit proper driving behaviour, thereby reducing the probability of driver errors and enhancing driving comfort.

A road accident is generally the end result of a multi-step process. The result of combinations and interactions between the three parts of the system (driver, road and vehicle) contribute to the traffic accidents. The aim is to understand the contribution of human factors and road characteristics to road accidents, in order to find the way to reduce accidents. For understanding the process of accidents the human factors and the road characteristics in the development of the accidents have to be examined. A clearer understanding of the role of these factors and characteristics will significantly contribute to the enhancement of road safety.

2.3.2 Self-Explanatory Road Environments in Practice

There are two main issues regarding self-explanatory roads (SER), on which IN-SAFETY (De Brucker et al. 2006) has focused: the first issue is related to the degree to which the total design of road environment, including road layout, contributes to creating a SER environment (through a process of prioritising road

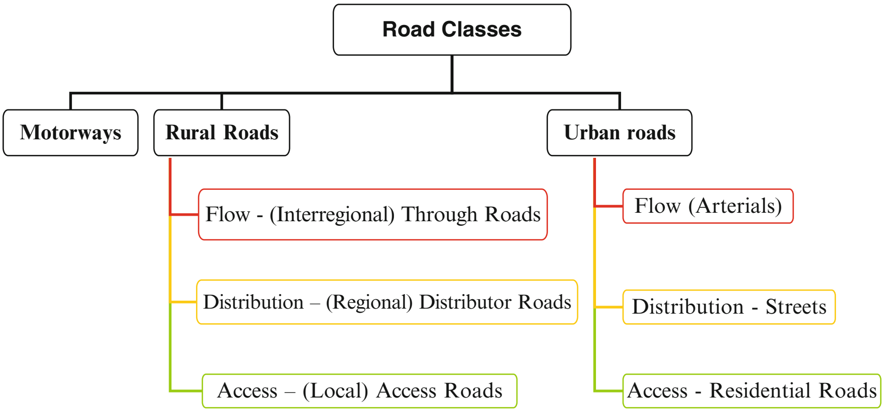

Fig. 2.1 Suggested road classes for self-explanatory roads (Matena et al. 2008)

accidents, followed by designing, choosing alternative measures to prevent these types of accidents and prioritising, using multicriteria analysis – MCA). The second issue is related to the readability and understandability of VMS messages (through an analysis of existing VMS, the design of alternative VMS, as well as the design of new VMS, followed by a user test).

The features that contribute to the creation of self-explanatory road (SER) environments were identified (and quantified) within the project and refer to (1) a sound road categorisation system, (2) assurance of sufficient time for the driver, (3) a safe field of vision offered to the driver and (4) respect for driver expectations. On the basis of these features, 14 recommendations for the development of variable message signs (VMS) have been formulated within the IN-SAFETY project. These refer to the size and design of pictograms, visual performance, text message and combined message recommendations, comprehensibility, route guidance, selection control, place of VMSes, distances between VMSes, combining several types of signals, changing messages in time and place, information overload and information absence. All these are further analyzed in Chaps. 13 and 14 of this book.

On the other hand, another EC funded research initiative, RIPCORD-ISEREST (506184), dealt with self-explanatory roads, merely from the infrastructure point of view. In it, among others, the concept and elements of self-explanatory roads were discussed, good practices identified and recommendations for self-explanatory road classes suggested (Matena et al. 2008) (Fig. 2.1).

2.4 Initial Concepts on Measures Promoting SER and FOR

The European transport system needs to be optimised to meet the demands of constant traffic enhancement and sustainable development. A modern transportation system must be sustainable from an economic and social as well as an environmental viewpoint. The principles of forgiving and self-explanatory road environments are among those which could contribute towards such an achievement.

In terms of forgiving road environments, the identification of error patterns that lead to accidents is the first step, in order to conclude to measures to be taken for rendering a road environment of forgiving nature. What is of outmost importance is to select the appropriate measure for each type of error, either in terms of infrastructure enhancement or application of telematics, or even their combinations, which are seen as the most promising solution, especially in terms of cost-efficiency.

As it has been seen, regarding self-explanatory road environments, several human factors depend on the traffic environment and there is no possibility to influence all of them. To lower the rate of accidents, the environment needs to be changed, most notably the road characteristics. Road characteristics that are suitable to human nature, and supply the driver with a clear, understandable picture about the given situation, have to be ensured. Such a road can be called a self-explanatory road.

Within IN-SAFETY, a set of measures have been proposed, as seen in the Table 2.2, covering both cases.

In Table 2.2, the alternatives that contribute to FOR only are represented in non-shaded cells and italics typeface. All the alternatives contributing to a SER environment are shaded cells. Those that contribute to a SER environment only are represented in black normal typeface. Those contributing to both SER and FOR (under specific circumstances) are represented in black, italics typeface, in shaded cells.

Reaching the deadline of 2010, set by the White Paper (COM 2001) road environments should, at the most possible degree, secure that people and goods can be transferred quickly, environmentally friendly and safely. This is a pre-requisite for the road transport to evolve towards the direction of sustainability, which is considered as the most promising feature for the future of transport.

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