

Self-explaining and forgiving roads

Need for action on rural roads

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Abstract

In accordance with the globally recognized Safe System Approach, the road system should be designed to compensate as much as possible for the error-proneness and vulnerability of road users. Regarding road infrastructure, this approach requires consistent consideration of the criteria for self-explaining and forgiving roads – in short: SERFOR. In the context of an overarching national research package on SERFOR, the present study addresses needs and measures for SERFOR-measures on rural roads in Switzerland. Considering the central aspects of human factors theory, the most important design rules have been formulated. These design rules are the key linking element between aspects of human factors theory and SERFOR measures in praxis. In the study, a total of 48 SERFOR measures were identified and rated by experts. In addition, recommendations for action to raise awareness, standardization and implementation as well as the need for further research were established.

Keywords

Road safety, Self-explaining roads; forgiving roads; rural roads; design rules; human factors, safety measures

Introduction

In accordance with the globally recognized Safe System Approach (Larsson and Tingvall, 2013), the road system should be designed to compensate as much as possible for the error-proneness and vulnerability of road users. Regarding road infrastructure, this approach requires consistent consideration of the criteria for self-explaining and forgiving roads. The term and the concept of “self-explaining roads” (SER) was defined in the 1990s (Theeuwes and Godthelp, 1995; Theeuwes, 2021) and expanded with the concept of “forgiving roads” (FOR) (RISER-Consortium, 2006). With the SERFOR research package, the Federal Roads Office FEDRO aims to develop concrete and practice oriented SERFOR measures in four sub-projects, and to demonstrate the need for action in Switzerland. Incorporating the latest findings in traffic psychology, the objective is to make urban and rural roads more self-explaining and more forgiving. Embedded in a comprehensive research package, in which first general design principles based on human factors were elaborated (Hackenfort, 2019), the present paper focuses on SERFOR measures for rural roads. In a parallel sub-project, urban roads are investigated.

Aim

The aim of the sub-project “Need for action on rural roads” is firstly to identify SERFOR aspects in existing standards and regulations, to further highlight them and to enhance them with suitable new

measures. Secondly, to find ways to better incorporate existing SERFOR measures, which to date have only been implemented to a limited extent into the planning and design of road projects.

Limitations

There are essentially two options for making roads in rural areas more self-explaining and forgiving: optimal alignment and cross-sections when planning new roads, and remedial measures to make the design of existing roads more self-explaining and forgiving. Optimal designs of cross-sections include, for instance, a width that is in accordance with the speed limit. Provided that the general conditions such as spatial factors, economic viability, etc. permit, the optimal alignment of the road and optimal cross-section should be favoured over remedial measures. However, because Switzerland already has a very dense road network, the research project focuses on remedial measures.

Relevant psychological factors in road traffic

Regardless of the mode with which a person participates in road traffic (pedestrians, cyclists, motorized vehicles), there are several psychological aspects that are relevant to the safe design of the road area. The most relevant ones are (Anderson, 2020; Badke-Schaub, 2008):

1. Perception: Those involved in road traffic must be able to perceive external stimuli (e.g. signals, road layout, weather conditions, etc.) as well as internal stimuli (e.g., fatigue, discomfort, etc.).
2. Recognition: Those involved in road traffic must recognize the external and internal stimuli as relevant to them.
3. Understanding: Those involved in road traffic must understand the meaning and implications of e.g. markings, signals, etc.
4. Motivation. Those involved in road traffic must be willing and motivated to follow the signaling, markings and instructions in their behavior.

These very general factors apply to all road users and are not specific to certain groups of people.

Methodology

The approach to achieving the aims is divided into the following successive work steps:

1. Step 1: Establish design rules considering psychological factors: Two experts of the advisory commission and three members of the project team group prioritized the road design principles (Hackenfort, 2019), taking into account the relevance for rural roads, the relevance for traffic safety and the relevance in the existing network from a practical point of view.
2. Step 2: Review design rules in existing standards: To assess how well the design rules have already been considered or even embedded into the existing standards and regulations in Switzerland, selected standards were reviewed, and technical discussions held with three recognized Swiss standardization experts.
3. Step 3: Identify and document SERFOR measures: The identification of the SERFOR measures and the preliminary analysis “Self-Explaining and Forgiving Roads” (BFU, 2016), as well as by conducting a broad analysis of international literature.
4. Step 4: Review practical feasibility and relevance of identified SERFOR measures: The identified measures were reviewed and evaluated by six Swiss experts in terms of their practical feasibility and legal implementation. Additionally, the project team assessed the relevance of the measures based on accident data for the years 2016–2020 in Switzerland.
5. Step 5: Evaluate and prioritize SERFOR measures: In an intensive workshop, six experts in two independent groups prioritized the total of 48 SERFOR measures, considering their effectiveness and their innovative content. Effectiveness was defined as the degree to which an approach was expected to reduce the number of accidents and/or the consequences of accidents at a specific point in the road network.

Based on the results of the work steps 1 to 5, the need for action to promote SERFOR philosophy in Switzerland was finally derived.

Results

Step 1: Definition of Design-Rules

SERFOR measures which aim to increase the self-explaining potential of the road design should be oriented towards and support the four mentioned main psychological principles. To the end, six so-called “design rules” were developed: Hence, a self-explaining and forgiving road should

1. provide orientation: The road environment and roadside surroundings should be equipped with design elements that encourage a correct perception of distance and/or speed by road users.
2. attract attention: The road environment should be equipped with salient, i.e. conspicuous, dynamic or adaptive traffic signs to draw the attention of road users to critical areas.
3. promote standardisation: Road design elements and cues that apply to similar road situations should have a uniform design.
4. support detection of conflict opponents: Intersection areas should be designed in such a way as to ensure that potential conflict opponents are within the range of vision of other road users (especially in conflict areas) and can be detected at an early stage through adequate visibility. In addition, or if this is not possible, e.g. due to structural constraints (spatial conditions, heritage or other protection measures, etc.), conspicuous elements – dynamic or adaptive – should support the direction of sight to potential conflict opponents.
5. improve clarity: Signs and markings should be positioned in the road environment and signage density kept as low as possible so as to ensure optimum visibility and perceptibility.
6. provide passive safety: On the one hand, drivers must be made aware as early as possible that they are leaving the preferred route. On the other hand, the road environment, including the roadside surroundings, must be designed in such a way as to minimise the consequences in the event of an accident.

While the first five design rules address SER, the last one relates to FOR.

Step 2: Review of existing standards

The review and technical discussions among experts on how the design rules are embedded into the existing standards and regulations in Switzerland have shown, that some human factor principles are already embedded into the road design codes. However, this has been done in a rather implicit manner: SERFOR is often described in broad and unspecific terms providing degrees of freedom in the interpretation to the applicants of the standards. This counteracts the third design rule of achieving a high level of standardisation in road design. It has also become apparent that an early identification of the opportunities and measures to include human factors experts and SERFOR measures in standardisation activities and practical safety work are crucial for the future of safe road traffic in Switzerland.

Step 3: Identification of SERFOR measures

Overall, 48 SERFOR measures were identified and documented. Of the 48 measures, 38 are categorised as SER and six as FOR measures. Four further measures can be assigned to both categories. The measures can be assigned to different road design elements:

- Measures that focus on the road cross-section such as the installation of central, separating and guiding islands for pedestrians or “rural core lanes”, lanes without central markings and outer cycle lanes, with a temporary reduction from two to one carriageway.

- Measures to change the texture of the road surface, such as:
 - curved, height-bridging pavers with the purpose to draw attention to transitional zones,
 - rumble strips across the direction of travel to increase alertness,
 - rumble strips in the middle of the carriageway or for outer carriageway demarcation.
- Measures to equip the road with transversal markings or markings along the centre line or carriageway edge lines, as well as speed-dependent edge line colouring to provide orientation.
- Measures to equip the road with signage, such as installing congestion detectors to focus attention or advanced reflective sheeting on road signs to improve clarity.
- Measures to landscape the roadside area
 - by means of planting vegetation (hedges, bushes),
 - removing plantings with big collision impacts (especially trees) from the roadside area in the sense of FOR,
 - installing traffic management systems to provide orientation,
 - installing elements to reduce sight distances and thus boost alertness.

Step 4: Assessment of practical feasibility and relevance

The evaluation of the identified measures showed that 11 measures could seamlessly be implemented already today. However, the remaining 37 measures may face different issues such as

- legal issues, for example lane light markers,
- political and financial challenges, for example continuous paved road verges,
- acceptance issues due to unacceptable changes to the landscape or noise pollution.

Accident data for the years 2016–2020 in Switzerland was also used to assess the relevance of the SER or FOR measures. The relevance was estimated as a function of the accidents potentially affected by the individual measure in Switzerland. According to the accident occurrence analysis, the most relevant SER and FOR measures are those which can prevent common accidents such as single-vehicle accidents. Therefore, these measures can potentially be used in numerous locations and prevent many accidents. For example, such measures are:

- Rumble strips in the middle of the carriageway
- Transversal markings along the centre line
- Oversize centre line markings.

Step 5: Prioritization of SERFOR measures

Prioritising the identified measures by expected effectiveness and innovation characteristics ultimately resulted in 20 priority SER and five FOR measures, which were further pursued and summarised in factsheets (see table 1). When prioritising the SERFOR measures, it became apparent that their impact can be viewed controversially in some cases, depending on whether they are looked at from a SER or a FOR perspective. This becomes particularly clear with measures that involve adding or removing roadside planting. Whereas plantings from a SER perspective provide orientation and may be desirable in the shape of hedges and bushes, from a FOR perspective, they constitute a risk to drivers if the planting includes e.g. trees. Furthermore, the prioritisation has shown that self-explaining road characteristics are also particularly important in transitional zones, i.e. areas connecting different network elements, such as between open road and tunnel sections or the transition from rural to urban roads.

Table 1: Prioritized SER- and FOR-measures for rural roads.

Title	Description
Central, separating and guiding islands for pedestrians	Centre island: traffic islands that simplify crossing a road for cyclists and pedestrians and offer opportunities for a stopover, as well as clarifying access without right of way in the sense of standardisation. Separation island: in crossing areas for the separate guidance of traffic flows. (Herrstedt 2006)
Curved, height-bridging pavers with the purpose to draw attention to transitional zones	Temporary comfort reduction through rocking/shaking due to curved, height-bridging pavers. The driver's attention should be increased. (Herrstedt 2006)
Rumble strips in the middle of the road	Audible and perceptible warning, usually pressed into the asphalt. Does not yet exist in this form in Switzerland. Not to be confused with "singing line", this would only be generated by markings. (ATSSA, 2016)
Rumble strips on road edge lines	Audible and perceptible warning markings, usually pressed into the asphalt. This already exists in Switzerland. (ATSSA, 2016)
congestion detector	Sign that lights up automatically in case of congestion, coupled with system that detects congestion.
Adaptive sign for wrong-way driving	Warning sign that is activated as soon as a driver drives in the wrong direction (e.g. motorway exit).
Modern retroreflective signs	Improved retroreflective sheeting for better visibility of signage. No longer glass beads on aluminium substrate, but "Diamond Grade". Visibility up to 1500 feet.
Standardized sign usage for changes in traffic flow around construction sites	Through a standardised signage and traffic guidance philosophy, construction site areas become more self-explaining, i.e. above all the routing becomes easier and more recognisable, it is more uniform and intuitive everywhere. (Herrstedt 2006)
Oversized centre road line	Permanent narrowing of lane widths to avoid overtaking and reduce speeds. Visual (sometimes audible) underpinning of an overtaking ban, possibly influencing speed. (Herrstedt 2006)
Lanes without centre road-lines and outer cycle lanes, with a temporary reduction from two to one carriageway	Increased attention and reduction of speed because there is only one central lane with edge lines as an alternative (visual narrowing of the lane). Today, this is unusual in extra-urban areas (except for reasons of space). In urban areas, core lanes are built to provide more space, especially for cyclists. That is not the goal here. (Herrstedt 2006)
Optical speed bars (at the edge of the road)	The markings give a better sense of speed and cause a reduction in speeds. In addition, they can also serve as a distance measure to vehicles in front. In addition, they also visually narrow the lane width and thus reduce speed.
Planting vegetation (hedges, bushes) on the roadside area	Plantings provide orientation, help with early recognition of road elements and promote awareness of the speed travelled. (Piar, 2016)
Removing vegetation from the roadside area	E.g. removal of trees to improve / increase the safety zone.

Title	Description
Road signs (posts, edge lines, arrows, ...)	The elements provide a clear line of reference / a clear visual guidance and orientation. (Piarc, 2016)
Coloured road shoulder	Paved shoulder for better control of the vehicle. To avoid excessive speed, a different colour should be chosen for the road shoulder. This prevents the perception of a wide road.
Reduce visibility along the road	Excessive visibility leads to less attention and high approach speeds at intersections. Visibility protection as a reduction of visibility in the approach area, not at the intersection.
Signs optically indicating the course of the road	Visual emphasis of the lines and curve radius through coloured or black and white elements. (Piarc, 2016)
speed-dependent edge line colouring	Depending on the speed to be selected, border lines can be marked green, yellow or red. Green = 80 km/h, yellow = 60 km/h, red = slower than 60 km/h.
markings for motorcyclists along the centre road lines markings in curves	Ground markings warn the motorcyclist that cornering too close to the centre line carries the risk of hitting the oncoming lane with the head and upper body.
Rumble strips perpendicular to the direction of travel	Transversal rumble strips before tight curves; high effectiveness (SER) for the prevention of motorbike accidents on popular and high accident risk motorbike routes.

Conclusions and need for action in Switzerland

In order for the measures identified and prioritised in this project to be implemented, action is needed at various levels. Structured into four groups, it includes the following general aspects:

- Raising awareness: Politicians, decision-makers and network operators, authorities, associations and specialist bodies must be made aware of the key aspects of consistent road safety work taking into account the central aspects of human factors psychology.
- Standardisation: Strive to increase standardisation by creating nationwide uniform definitions for implementation, processes and action plans. Incorporate the SERFOR measures from this research package into the standards and guidelines for road design. Establish trans-disciplinary code writing groups, including specialists on human factors.
- Implementation: Implement the SERFOR measures in safety work and road design based on the appropriate knowledge transfer of the standards and recommendations to all user groups.
- Consolidation: Close existing gaps in the research, e.g. with a look to the future, concrete implementation of individual SERFOR measures and their potential impacts.

These recommendations for awareness raising, standardization, implementation and deepening should ultimately contribute to a (safety) culture development in road transport that proactively, theoretically substantiated and, where possible, empirically tested and systematically considers human factors in the design of infrastructure, standards and specifications in the sense of a safe-system approach. In many areas, the importance of human factors for the formulation of norms, rules, specifications as well as the design of infrastructure is already recognized, but their consideration should be even more systematic and explicit at all political and societal levels by the relevant decision makers. It is also important to bear in mind that such cultural developments also require sufficient

time and should be approached gradually in the sense of “research → implementation planning → training → implementation in practice”.

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