Most common road safety engineering deficiencies in South Eastern Europe as a part of safe system approach

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Abstract. Most common road safety engineering deficiencies identified by the authors in South Eastern Europe, including Romania, have been collected together and presented in this paper as a part of road safety unbreakably connected to the safe system approach (driver-vehicle-road). In different South Eastern Europe countries Road Safety Audit (RSA), Road Safety Inspection (RSI), as well as Black Spot Management (BSM) was introduced and practical implementation experience enabled the authors to analyze the road safety problems. Typical road safety engineering deficiencies have been presented in 8 different subsections, based on PIARC (World Road Association) RSA approach. This paper presents collected common road safety problems with relevant illustrations (real pictures) with associated accident risks.

1. Introduction
After almost 15 years of experience with RSA and RSI and even more with BSM in South Eastern Europe, these procedures are now recognized as one of the most efficient road safety engineering tools. RSA/RSI are highly efficient and cost effective engineering tools for improvement of safety on roads, because it is much cheaper to identify road safety deficiencies in the process of design than later after construction is completed and accidents start to happen RSA/RSI are among the most cost-effective investments a Road Authority can undertake.

With its EU Directive No. 2008/96 on road infrastructure safety management, published in October 2008, the European Union (EU) made a clear decision that all three mentioned procedures will be mandatory for the Trans-European Road Network (TERN) in the coming years [11]. Unfortunately, in reality systematic application of RSA/RSI in South Eastern Europe is only partial. Where RSA/RSI are implemented they are mostly pushed by IFIs (WB, EIB, EBRD, etc.) and implemented by foreign consulting companies. The situation with BSM is better and the level of implementation is higher. However, even when procedures are undertaken, the proposed recommendations (measures) are not always implemented by the road authorities. EU funded Projects have tried to develop capacity for RSA/RSI implementation in each of the South Eastern Europe countries. Therefore, in South Eastern Europe important steps towards RSA/RSI implementation have been taken. Each country now has several trained auditors, a different Road Safety Audit manual has been produced and certain Pilot road sections have been audited. In almost all South Eastern Europe countries, RSA has been introduced into the legislation as a mandatory procedure. A similar or even better situation exists with BSM.

Within this paper, the authors try to make summary of their findings based on their implementation experience of RSA, RSI and BSM in South Eastern Europe countries. The paper follows the PIARC RSA/RSI approach and classifies identified road safety deficiencies into 8 broad groups or categories (subsections 3.1 to 3.8) [19].

2. Statistical data regarding the severe roads accidents in Romania
Despite some positive trends, road safety represents still a big challenge for Romania. Together with Leetonia, Bulgaria and Lithuania, Romania is one of the four European Union countries with the biggest road safety accidents rate where victims are involved. With a rate of 95 fatalities for one
million inhabitants, the rate of road safety accidents in Romania is three times bigger than other performant countries in European Union, like Sweden, United Kingdom or Nederland [17].

In addition, the motorization degree of ~200 passenger cars for 1.000 inhabitants, Romania is much below the European Union average, but based on trends and estimations, they will drastically increase in the following years. This fact might contribute or increase the number of road accidents in the future, if preventive measures are not considered and implemented.

Considering the development of the specific dynamic indicators between 1990 – 2014 (figure 1), we could observe a strong growth trend for the period 2003 – 2008, which was then reversed into a decreasing trend. Roads accidents have dropped with 35%, from 2,796 in 2009 to 1,818 in 2014, but injuries have dropped with only 9% for the same period, from 15,295 to 13,237. In the same time, Romania registered a constant increase in the number of vehicles with a long term growth trend of 5% per year [17].

**Figure 1.** Specific dynamic indicators regarding the road accidents situation for Romania between 1990 – 2014 [17].

Based on the information published by the European Transport Safety Council (ETSC) in 2015 (figure 2), from 2001 (reference year when was set the objective for road accidents fatalities number reduction) to date, Romania has the worst performance, together with Malta, Bulgaria and Poland [17].

**Figure 2.** Fatalities number development as a consequence of road accidents in European Union between 2001 – 2014 [17].

There was an improvement of this indicator during 2010 – 2014, when the number of victims from road accidents decreased in Romania with 23,5%, above the European Union average of 18,2% (figure 3) [17].
3. Typical road safety engineering deficiencies

The most important road safety deficiencies identified within South Eastern Europe are briefly presented along with typical problems, illustrations of unsafe design and estimates of expected accidents that may occur in practice. Pictures from South Eastern Europe countries are used for illustrations of problems.

3.1. Road Function. Roads with mixed function (Linear settlements)

Typical problems: mixed road function (usage of the road as fast distributors for fast longer distance motorized traffic and as a route for slow local traffic) causes one of the major road safety problems in South Eastern Europe. This is one of the common problems where the rate of expansion of isolated communities along a road can rapidly reduce the effectiveness of a nationally or regionally important route as a result of the local traffic activities overwhelming the through route function of the road.

Examples of unsafe designs are presented in figures 4 and 5, for 2+2 road without median.

In such cases, the role of the road in the road hierarchy becomes confused. While the road is passing through settlements (where no by-pass exists) can it keep its geometry unchanged? Can it even be called International/Regional/National road, or does it become a street? This, simple planning (designing) confusion of local administrations, can cause tremendous problems in road safety. Once intense development has been allowed, it is very difficult to achieve improvements without major reconstruction on a new alignment. Often even when a bypass has been built, the village often, over time, extends out across to the new road. This is mainly an issue of poor access control and development control by relevant authorities [4], [5], [18].
Expected accidents: pedestrians crossing street outside a junction; pedestrians in the road; at least two vehicles - same direction - rear end collisions; at least two vehicles - head on collision in general; at least two vehicles - same road - opposite direction - turning left (right) in front of other vehicle, etc.

3.2. Cross Sections. Types of cross profiles (Width of the road)
Typical problems: a cross section will normally consist of the carriageway, shoulders or kerbs, drainage features and earthwork profiles. It may also include facilities for pedestrians, cyclists or other special user groups. There is some evidence to suggest that widening lane or carriageway width or widening shoulders up to a certain extent is beneficial in reducing certain types of accidents. However, beyond a certain point it can have negative effects on road safety (users will start using extended width as a regular lane). Dangerous cross sections of express roads and highways are frequently being used in South Eastern Europe participants, including of Romania. For example: four lane road without a crash barrier or two lane road with wide hard shoulders. A road with a wide hard shoulder can sometimes be misused by drivers as a very narrow four lane road, with disastrous results and very serious crashes [1], [2], [3].

Examples of unsafe designs regarding the cross sections of the road are presented in figures 6 and 7.

![Figure 6. Too narrow acceleration lane.](image)

![Figure 7. 1+1 Width wide hard shoulders.](image)

Cross sections, particularly on roads through built up areas, are often not uniform or consistent. Local developments may encroach onto the carriageway because of the lack of effective planning control. In rural conditions cross sections may be reduced at drainage structures causing sudden changes in width.

Steep side slopes, introduced for drainage purposes, do not allow a driver to recover in case he leaves the carriageway, and thereby add to the likelihood of an accident. Open channel drains can also increase the probability that driver error will result in an accident.

3.3. Alignment. Vertical and horizontal curves (Consistency)
Typical problems: unexpectedly tight horizontal curves can lead to accidents as drivers try to drive through them at too high a speed. A similar situation may occur on horizontal curves in other similar hazardous situations, such as steep gradient or after a long straight section where driver is encouraged or misled (by the approach geometry) to think that he can drive at higher speed than is safe for that location. The sight distances associated with larger curve radii may also encourage driver to overtake in unsafe conditions [6], [7], [8].

Poor co-ordination of the horizontal and vertical alignments can result in visual effects which contribute to the accidents and are detrimental to the road appearance. Unsafe combinations of horizontal and vertical curvature are likely to be misinterpreted by a driver and can result when horizontal and vertical curves of different length occur at the same location. These situations are particularly dangerous and are unfortunately frequently present in South Eastern Europe.
Two examples of unsafe designs, with respect to the alignment, are presented in figures 8 and 9 (for sharp curve).

![Figure 8. Example no. 1 of unsafe designs.](image1)

![Figure 9. Example no. 2 of unsafe designs.](image2)

Expected accidents: single vehicle accidents in a bend - going either side of the road; at least two vehicles - head on collisions in general; at least two vehicles - same direction - rear end collisions; etc.

3.4. Intersections. Channelization of traffic flows

Typical problems: channelization is a useful tool in traffic management. It should be applied to all junctions on high speed roads. This may require local widening but the small additional cost of this at the design stage will be offset by future safety benefits in almost every case. Consideration of the access needs of emergency and other priority vehicles is required, especially in the event of an accident or breakdown. If provision is not made for this, damage to kerbs will quickly occur.

Channelization guides the driver through the conflict points, provides safe areas for him to stop while making a maneuver and reduces conflicts between different flows of traffic. Channelization by means of road markings, raised kerbs, traffic islands and bollards, can be used to guide vehicles along a specific path on the approach to and/or exit from a junction and to position them at the safest location to make their maneuver. The benefits of this are that movements are simplified, less confusion arises and the number of conflict points is minimized [9], [10].

Traffic islands have the added benefit of providing a refuge for pedestrians crossing the road. They also provide a convenient location for street furniture such as signs, street lighting and drainage covers.

Examples of unsafe designs, with respect to intersections, are presented in figures 10 and 11.

![Figure 10. Confusion for drivers leads to mistakes.](image3)

![Figure 11. Unsafe “Y” type of intersection.](image4)

Expected accidents: at least two vehicles - same road - opposite direction - turning left (right) in front of other vehicle; at least two vehicles - crossing (no turning) – different; at least two vehicles - head on collision in general; at least two vehicles - same direction - entering traffic; at least two vehicles - opposite direction no turning – others; etc.
3.5. Public and private services. Services along roadside
Typical problems: roadside facilities (rest places and petrol stations) are necessary to serve the long distance traffic between regions and towns (villages). Drivers need to rest at least once every 2 or 3 hours in order to maintain their concentration when driving. It is useful to combine rest areas with petrol and/or service stations at 30 – 50 km distances. Entrances and exits to and from Service and Rest areas can cause a disruption to traffic on the main carriageway if they are not separated well, and special attention should be given to design and maintenance of deceleration and acceleration lanes. It is important that sufficient rest areas are provided at around 10 km intervals but not too many to avoid constant disruption of the main flow of traffic by constantly exiting and merging traffic. Such rest areas may be used for selling goods by local farmers to minimize such activity occurring along the road itself. Farmers should be able to reach such areas from minor roads behind the service area.

In South Eastern Europe participants there some examples where roads are encroached upon by unacceptable commercial services or where there are unsuitable rest areas. This is dangerous for all road users, because of huge speed difference and mixture of different categories of road users. This can result in sudden vehicle stopping of vehicles and sudden entry of vehicles into the traffic as well as presence of unprotected pedestrians on high speed roads [12], [13].

Master plans, land usage, urban development and restrictions in access to the public road network are key elements that can be used for preventing these types of accidents.

Some examples of unsafe designs are presented in figures 12 and 13.

![Figure 12. Unsafe Bus stop.](image1)

![Figure 13. Rest area, lack of separation, no regular exit.](image2)

3.6. Vulnerable road users need. Pedestrian crossing
Typical problems: pedestrians should not have to walk at all along interurban roads. Hard shoulders are not intended for vulnerable road users but for emergency use by vehicles only. With the exception of roundabouts, pedestrian crossings should ideally be grade separated on major roads if large numbers of vulnerable road users are expected. At-grade pedestrian crossing on dual carriageways or multi-lane roads should be forbidden unless traffic signals are provided. To enable pedestrians to cross safely, crossings should be provided as underpasses or over bridges with ramps, not stairs. Any other solution significantly increases risks of pedestrian accidents. Even though it is not in accordance with any road standards/norms in the world, including modifications (upgrade) of old German (DIN) and ex-soviet SNiP and GOST standards used in South Eastern Europe, there are many such examples where pedestrian crossings have been placed at the same level on an international road.

In order to provide additional traffic capacity at junctions, local widening is sometimes carried out but this can often increase the crossing distances - again creating increased risk for pedestrians.

Heavy crossing demands may sometimes occur away from junctions where vehicle speeds are very high and this is often the case in South Eastern Europe. The provision of underpasses or over bridges however may be too expensive and may not be well used. Designers and the road authority need to provide crossings which the pedestrians will be willing to use [14], [15].

Examples of unsafe pedestrian crossing designs are presented in figures 14 and 15.
3.7 Traffic signing, marking and light. Signing

Typical problems: warning signs and warning markings are used to give advance notice of a potential hazard ahead or of any unexpected feature of the road geometry. The signs are used in specific situations when there is a change in the road, such as on a bend, on a high speed road or on the approach to junction. The location of signs is very important because they should provide adequate warning or information at sufficient distance, however they should not obscure important road features. Of great importance for the visibility of the signs is that they be located in positions where overgrown vegetation cannot obscure the visibility of the sign. Signs must be visible at all times, so reflective materials should be used for night-time visibility and urban signs may require to be lit internally or externally. In some South Eastern Europe countries, it is common practice for the signs to be missing (even at dangerous locations), not properly positioned, without reflectivity, non-standardized or even not consistent with International UN Conventions [16].

Examples of unsafe designs are presented in figures 16 and 17.

A recurring problem with signs is of them being obscured, either by permanent features such as street furniture and vegetation or by parked vehicles and, on dual carriageways, by moving vehicles in the nearside lane (if there is no repeated sign on the other side of the road). Too many signs can detract from their objective by overloading the driver with too much information too quickly, which leads to confusion or to a situation where the driver ignores certain signs. Signs may not be visible at night time because of poor illumination, lack of routine maintenance, reliability/continuity of power supply or inappropriate positioning (too high, set back out of road or turned away from driver). If reflective signs are not regularly cleaned, they may not retain their design properties.

Expected accidents: pedestrians crossing street outside a junction; pedestrians crossing street at a junction; at least two vehicles - crossing (no turning) - different; at least two vehicles - same direction - rear end collisions; at least two vehicles - same road - opposite direction - turning left (right); etc.
3.8. Roadside features and passive safety installations. Roadside obstacles (plants, trees, light poles, advertisements, etc.)

Typical problems: the presence of roadside obstacles, street furniture (for example, road signs and lighting columns) advertising signs and trees has two safety implications. The first is the potential danger of collision, and the second is their obstruction of visibility. Visibility is important not only for the driver, but also to other road users. Obstructions caused by trees, for example, may result in pedestrians making unsafe decisions.

Great care should be taken concerning the positioning of roadside features which may either obstruct visibility, lead to accidents or increase accident severity. Where obstructions cannot be practically removed, and could contribute to hazardous situations, consideration should be given to their replacement with equipment designed to collapse on impact, re-alignment of the road, or the introduction of barriers. Once a road is completed, care must be taken to ensure that new obstacles are not introduced by other institutions subsequently, such as telephone or electricity authorities.

Vegetation should be trimmed regularly and planning controls should be enforced to prevent stalls and structures being too close to the road edge. In some South Eastern Europe countries, trees are often planted adjacent to roads in order to provide shade for pedestrians, animals and parked vehicles and in other countries to prevent the wind from bringing snow onto the road [19].

Some examples of unsafe designs are presented in figures 18 and 19.

![Figure 18. No guardrails at sharp curve.](image1)

![Figure 19. Dangerous start point of guardrail.](image2)

Expected accidents: single vehicle accidents with obstacles on or above the road; single vehicle accidents with obstacles - others; single vehicle accident - leaving straight road - either side of the road; at least two vehicles - same direction - rear end collisions; pedestrians walking along the road, etc.

3.9. Temporary signing and marking at Work Zones

Typical problems: a work zone is an area of road or roadside where construction, maintenance or other works are performed and which may affect the safety and limit the free movement of road users through and in the vicinity of the Work Zone. Work zones are zones on the road with higher risk of accidents for both road users (vehicle occupants and vulnerable categories) and workers. A Traffic Management Plan (TMP) of good quality should be made and followed so that all participants in traffic are protected against risk of a traffic accident. Such TMP should contain all elements starting from design, placement, and maintenance to the removal of all elements regulating the road traffic [19].

To minimize the problems and increase safety, work zone layout (marking and signing) requires special consideration for the following reasons:

- Work zone is a section of road where, most often, geometrical characteristics of the road and the traffic conditions are changed to poorer conditions (less safe). The types of executed works are often road construction, rehabilitation and maintenance, but there are other types of work
on the road that need the same treatment, for instance work with cables, pipes etc. located in the road area.

- Employees in work zones spend most of their working hours directly exposed to traffic. In accidents, happening in work zones, these employees are often the victims, and can often be at as much at risk as the road users.

The growing international transit traffic flow in South Eastern Europe implies the need for main traffic corridors to be constructed according to international standards and requires European standards and a widely recognized and consistent system for road works signing and work zone safety.

An example of unsafe designs is presented in the following figure 20.

![Dangerous working zone](image)

*Figure 20. Dangerous working zone*

Expected accidents: single vehicle accidents with roadwork materials; hitting parked vehicles right (left) side of the road; at least two vehicles - head on collision in general; at least two vehicles - same direction - rear end collisions; pedestrians walking along the road, etc.

4. Conclusion

Education and training of the auditors/inspectors is probably one of the weakest points in the entire safe system approach in South Eastern Europe countries. The reasons for this are relatively short history of RSA in the region, lack of understanding of RSA methodology and procedures and lack of RSA literature in local languages. This is why the team of safety engineering specialists, who are very well acquainted with conditions in South Eastern Europe, prepared an extended version of this paper called: “Practical Guide for Road Safety Auditors and Inspectors” with the specific intention to help present and future auditors/inspectors in their work across the region.

The Practical Guide is based on actual traffic situations identified as road safety deficiencies and draws upon best international practice and proposals for improvement (treatment). As South Eastern Europe countries contain important transport links (corridors), harmonization of road standards and elimination of potential risks for the road users are of utmost importance.

The main reason for presenting this paper was to help new auditors/inspectors and clients to recognize typical road safety deficiencies in road engineering that have been occurring in past designs and to prevent them in the design/construction and maintenance processes. Also, in the long term, such collated knowledge about typical road safety deficiencies can help lead to the improvement of road design standards.

The objective of the national strategy for road safety in Romania is to reduce with 50% the number of fatalities from cars accidents until 2020 compared with 2010. The specific objective is to reach a maximum of 1188 fatalities in 2020, compared with 2377 in 2010. In the same time, the general objective of the Strategy is to transform Romania in a safe country for its citizens, investors and tourists with regard to road traffic, by progressive reduction of the injuries from road accidents in 2016 – 2020. The vision of this strategy is to reduce the number of fatalities and serious injuries from road transport system as close to zero in order to sustain a good level of social and economic life conditions [17].
Acknowledgments
This Paper presents a digest from Practical Guide for road safety auditors/inspectors which builds to a large extent on international best practice, direct experience of the authors and draws upon detailed guidance and concepts in the 5 key publications indicated below:

1. “Towards safer roads in developing countries”, a guide for planners and engineers, developed by TRL, Ross Silcock partnership and ODA in 1991,
2. “The handbook of road safety measures”, written by Rune Elvik and Truls Vaa, in 2004
3. “Catalogue of design safety problems and practical countermeasures”, developed by World Road Association (PIARC) in 2009
4. “Romanian Manual for Road Safety Audits on Existing Roads (RSI) and on Road Design (RSA)”, developed by World Road Association (PIARC) in 2016
5. “National Strategy for Road Safety for 2016 – 2022”, developed by Transports Ministry of Romania in 2016.

The above 5 documents provide much more detailed guidance on all key aspects of safety engineering and authors recommend that road engineers should use these in planning and operation of roads to ensure safer road networks. We are grateful to the authors of the original documents for sharing their experience via these documents. All photographs used as illustration of the problems, or as best practices are provided by the authors.

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