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Improvement of road safety on rural roads by using suitable safety barriers

Schmitz, Susanne[a]*; Meisel, Linda[a]

[a]*Federal Highway Research Institute, Brüderstraße 53, 51427 Bergisch Gladbach,Germany*

Abstract

Safety barriers can deliver an important contribution to approach the aim of "vision zero". One main requirement for this task is the correct choice of suitable and safe barrier systems that fit the boundary conditions on-site. Usually the national guidelines for the application of safety barriers offer the required basic principles. However, the characteristics of some road types are far away from any standard. That is why some procedural guidelines are needed, to decide whether a construction is suitable for a special boundary condition or not.
Therefore some considerations were made with the aim to support the correct choice of suitable and safe barrier systems especially for constricted space conditions like trees close to the roadside. In addition a future option for tested barrier systems for such special-purpose solutions is drafted. The ideas and concepts developed in this context are described in the present paper.

Keywords: road safety; safety barriers; special installation situations; trees at roadside; European guidelines

1. Introduction

The aim of reducing traffic deaths is summarized under the keyword "vision zero" all over Europe. In Germany this aim was also adapted to the government programme. The current statistics DESTATIS (2018) show, that in 2017 on German roads 3180 people were killed in an accident, more than half of them (1795 persons) lost their lives on rural roads. And here 650 people, about 20 % of all traffic deaths in 2017, died in collisions on trees and other obstacles next to the roadside. Many more were heavily injured.

These numbers show, that here lies a relevant safety potential that can be activated by mitigating these dangerous boundary conditions for approaching the vision zero. One option is to eliminate the obstacles next to the roadside to avoid a crash from deviating vehicles from the road. But especially in cases of avenues or trees, that deserve to be protected, this option often does not exist. If the elimination of the obstacle is not possible a second option for mitigating is the installation of safety barriers in front of the obstacles to attenuate the consequences for the passengers of a crashing vehicle.

Therefore the German Federal Ministry of Transport and Digital Infrastructure (BMVI) released a program to safeguard obstacles next to the roadside (distance < 4.50 m) with safety barriers in 2017. It covers the retrofitting of safety barriers on existing federal trunk roads. The main aim of this program is to reduce the number of traffic

* Corresponding author. Tel.: +49-2204-43-4411;
E-mail address: ref-v4@bast.de

deaths overall as well as the reduction of the general injury severity in traffic accidents with obstacles. The term of the safeguard program is at least 5 years.

To transfer this aim to the rural roads and equip the relevant areas with suitable and safe barrier systems, numerous technical considerations have to be carried out. With the aim to support the road administrations in installing safe barrier constructions and to promote consistent solutions, the long term experience of all involved parties was collected and published. Nevertheless therefore some challenges have to be solved which are described in the following.

2. Todays challenges

In Germany the application of safety barriers is regulated in the guideline RPS 2009 (2009). Additional advice for the installation can be found in the application recommendation for the RPS 2009 in BASt (2019). In these guidelines the standard applications for all road restraint systems are covered which mainly deal with the regular boundary conditions without any restricting issues. As explained above, the focus of the safeguard programme lies on the rural roads as they show a relevant number of severe collisions with trees and other obstacles next to the roadside. However, the characteristics of this road type are often far away from any standard guideline due to road width, the number and distance between intersections as well as the free space next to the roadside. That is why the general requirements of the standard guidelines for safety barriers often cannot be met, since it is not possible to install them with the recommended distance from an obstacle or the required barrier length on-site. Frequently found examples for those special installation situations are single obstacles with a short distance next to the roadside, avenues and tree lines as well as intersections with access roads, see Fig. 1.

Fig. 1 Example for an avenue with constricted boundary conditions for the installation of safety barriers

To protect these dangerous areas in a suitable and safe way, only very few special safety barrier solutions are available on the market. However, thus are not able to cover all cases of the installation situations on-site so that reasonable compromise between a regular installation and the best safety result is necessary.

According to the manufacturers one reason for missing barrier solutions lies in the lack of clearly defined testing conditions and evaluation methods. This describes another challenge that has to be faced, since the current European standard for the approval of road restraint systems, the EN 1317, does not include testing conditions and acceptance criteria for special-purpose solutions. For example, short barrier constructions for single objects may show characteristics of a safety barrier a well as a terminal or a crash cushion, see Fig. 2.

Fig. 2 Example for a short barrier construction to protect a single obstacle next to the road

In this case it is not clearly defined, if a safety barrier construction has to be tested according to the EN 1317, Part 2 for safety barriers, the EN 1317, Part 3 for crash cushions or EN 1317, Part 4 for terminals and transitions. In doubt, all crash tests of Parts 2, 3 and 4 have to be carried out. But since these tests are related to a high expense, the manufacturers usually only carry out the type tests according to one separate part of the EN 1317, condoning the fact that other important characteristics of the barrier cannot be declared. In addition, carrying out all possible tests might not be very efficient because some of the tests are quite similar.

To underline the challenges of constricted space conditions a further example for those special-purpose solutions, like curved barrier constructions with a small radius to be installed at intersections with access roads, is shown in Fig. 3.

(a) (b)

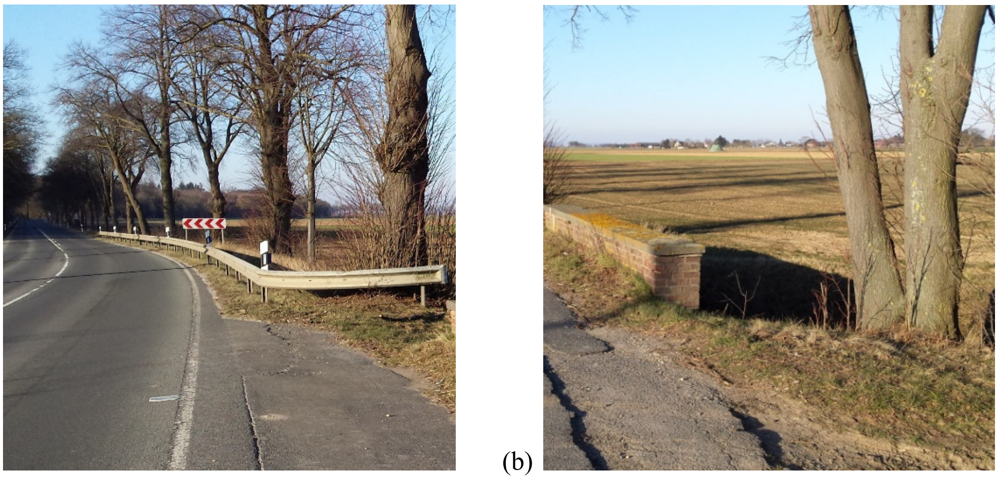


Fig. 3 Examples for (a) a curved barrier; (b) a not protected obstacle (distance < 4.50 m)

The missing testing conditions and acceptance criteria relating to the lack of suitable barrier systems especially for constricted space conditions lead to the challenges road administrations have to face today. In order to implement the safeguard programme they rather have to plan single solutions for every site which is connected to an enormous effort and in addition includes the risk of constructional faults. In cases they do not find suitable solutions, the obstacles that represent a safety risk might not be protected at all, see Fig. 3. Furthermore the chosen constructions for the same boundary conditions might vary, since diverse departments of the road administrations are involved.

To close the gap between the requirements of the safeguard program and the missing suitable barrier constructions, the idea of a consistent basic concept to mitigate the dangerous boundary conditions on rural roads was born. Therefore some procedural guidelines and a draft for further steps were developed, to decide whether a construction is suitable for a special boundary condition or not, respectively which verification is necessary to prove that a special-purpose solution is suitable and safe. They should support the realisation of the safeguard program and contribute to the improvement of traffic safety on rural roads.

3. Practical implementation and ideas for the future

3.1. Tree Compendium

To support the safeguard programme as well as the road administrations in charge the Federal Highway Research Institute developed a compendium, which picks up the above mentioned challenges and offers ways to find suitable and safe barrier solutions for special installation situations. It was drafted considering the long term experience of the road administrations as well as the knowledge of manufacturers of safety barriers. The *Compendium for special solutions to safeguard trees and other obstacles at rural roads (Tree Compendium)*, BASt (2017), was published in December 2017. It describes all relevant aspects that have to be considered for developing a suitable and safe solution to safeguard special installation situations with constricted space conditions on rural roads.

In a first step usual examples of the boundary conditions on rural roads were collected. Therefore an enquiry was set up, in which the road administrations should collect typical situations with constricted space conditions they are often faced with in their daily work. In step two these examples were structured in topics like single obstacle, tree lines and avenues as well as intersections with access roads. Afterwards the best possible solution to safeguard the obstacle was designed and documented. If possible, also a remodelling of the obstacles or boundary conditions was considered to avoid the requirement of safety barriers. As a result a catalogue of general advice was published.

The main aim during the implementation of the safeguard program is to find a solution for safeguarding the relevant areas by choosing the best possible solution on-site. Usually therefore an assessment process is necessary, in which the different arguments are discussed and which leads to the best possible compromise. The general advice given in the tree compendium, that is mentioned in the following, can be used for this task.

In some cases it is reasonable, to **reduce the regular motion distance** (in Germany 0.5 m) of the safety barrier from the roadside. With this measure the often restricted distance between obstacle and roadside can be used in an optimum way. Here it is important to regard the whole road width to avoid a too narrow distance between safety barriers on each roadside so that the encounter of relevant vehicles stays guaranteed. Another option for restricted space conditions is the **acceptance of obstacles within the working width**. The tree compendium provides a table of pros and cons of this two measures to support the assessment process.

A further aspect that has to be considered during the planning process of safety barriers with trees at the roadside it the **protection of the roots**. The rammed posts of steel barriers might cause a damage at the roots which contains the risk that the whole tree is sustainable marred. That is why safety barriers with larger post distances should be favoured if possible. In case of rural **roads through forests** the potential of deer crossings also has to be considered.

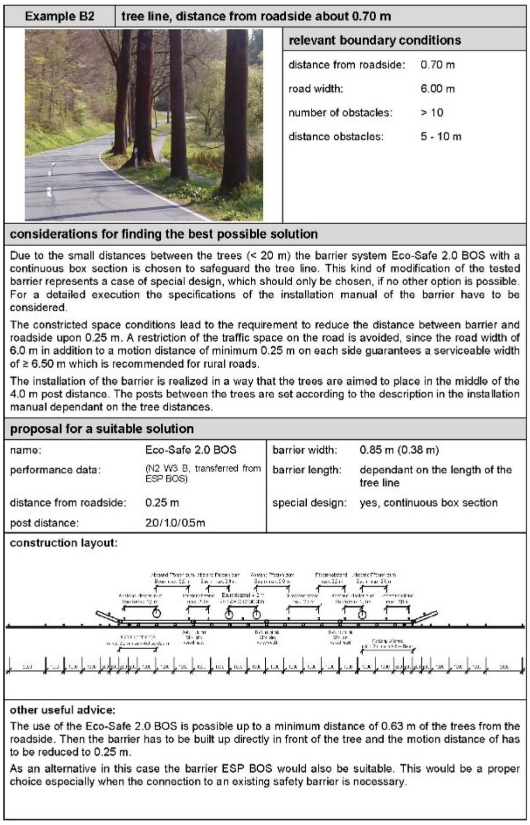
As already displayed in Fig. 2 and Fig. 3 rural roads often contain intersections with access roads. Especially in cases of access roads to agricultural areas the distance between the interruptions of the safety barriers is often very short, so that it could be difficult to install the **necessary barrier length** to guarantee the full safety effect. A suitable **configuration of the intersection** also can be a challenge, since the properties of curved barriers are nearly unknown so far (also see section 3.2). The tree compendium offers some experience based advice and alternatives how to deal with those situations and how suitable solutions might look like.

Further aspects dealt with in the tree compendium are the **additional protection for motorcyclists**, which might be necessary on winding roads, the configuration of **connections to existing safety barriers**, as well as references for the **traffic operation**, since for example a narrow post distance of safety barriers raises the effort for grass mowing next to the roadside. Regarding all relevant aspects for finding the best possible solution it is recommended, that the entire decision process is carefully documented.

Next to the general advice the tree compendium includes several best practice examples that should guide the user on his way to his own solution. They represent usual cases on rural roads and are explained in detailed fact sheets. These show the possible options to use available CE-marked barrier systems and, if necessary, explain how to adapt them to a fitting solution for the special situation on-site. Two examples of these fact sheets are displayed in Fig. 4. As it is shown, they are structured in a consistent way and contain the following information:

- Example Number and keyword as headline
- Description of the relevant boundary conditions including restrictions
- Visualization by picture
- Considerations for finding the best possible solution (assessment process)
- Proposal for a suitable solution including barrier characteristics, parameters and drawing
- Other useful advice

(a)



Example B2	tree line, distance from roadside about 0.70 m

relevant boundary conditions

distance from roadside:	0.70 m
road width:	6.00 m
number of obstacles:	> 10
distance obstacles:	5 - 10 m

considerations for finding the best possible solution

Due to the small distances between the trees (< 20 m) the barrier system Eco-Safe 2.0 BOS with a continuous box section is chosen to safeguard the tree line. This kind of modification of the tested barrier represents a case of special design, which should only be chosen, if no other option is possible. For a detailed execution the specifications of the installation manual of the barrier have to be considered.

The constricted space conditions lead to the requirement to reduce the distance between barrier and roadside upon 0.25 m. A restriction of the traffic space on the road is avoided, since the road width of 6.0 m in addition to a motion distance of minimum 0.25 m on each side guarantees a serviceable width of ≥ 6.50 m which is recommended for rural roads.

The installation of the barrier is realized in a way that the trees are aimed to place in the middle of the 4.0 m post distance. The posts between the trees are set according to the description in the installation manual dependant on the tree distances.

proposal for a suitable solution

name:	Eco-Safe 2.0 BOS	barrier width:	0.85 m (0.38 m)
performance data:	(N2 W3 B, transferred from ESP BOS)	barrier length:	dependant on the length of the tree line
distance from roadside:	0.25 m	special design:	yes, continuous box section
post distance:	2.0/1.0/0.5m		

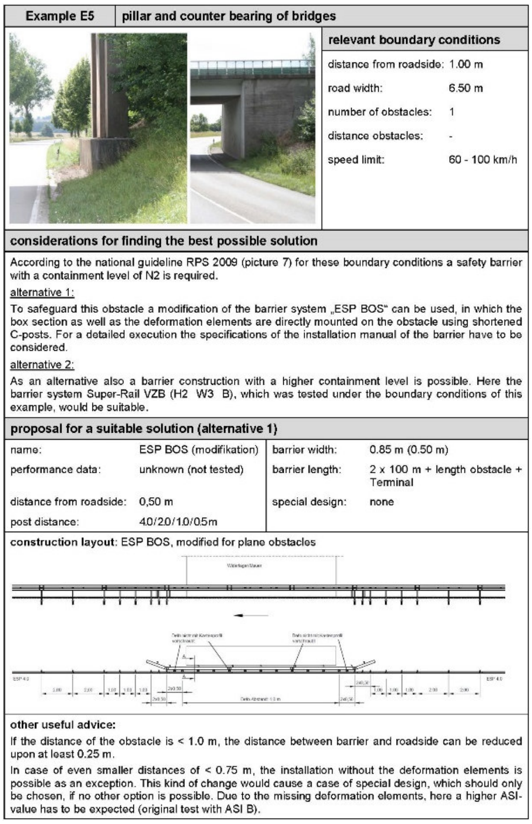
construction layout:

other useful advice:

The use of the Eco-Safe 2.0 BOS is possible up to a minimum distance of 0.63 m of the trees from the roadside. Then the barrier has to be built up directly in front of the tree and the motion distance of has to be reduced to 0.25 m.

As an alternative in this case the barrier ESP BOS would also be suitable. This would be a proper choice especially when the connection to an existing safety barrier is necessary.

(b)



Example E5	pillar and counter bearing of bridges

relevant boundary conditions

distance from roadside:	1.00 m
road width:	6.50 m
number of obstacles:	1
distance obstacles:	-
speed limit:	60 - 100 km/h

considerations for finding the best possible solution

According to the national guideline RPS 2009 (picture 7) for these boundary conditions a safety barrier with a containment level of N2 is required.

alternative 1:

To safeguard this obstacle a modification of the barrier system „ESP BOS" can be used, in which the box section as well as the deformation elements are directly mounted on the obstacle using shortened C-posts. For a detailed execution the specifications of the installation manual of the barrier have to be considered.

alternative 2:

As an alternative also a barrier construction with a higher containment level is possible. Here the barrier system Super-Rail VZB (H2 W3 B), which was tested under the boundary conditions of this example, would be suitable.

proposal for a suitable solution (alternative 1)

name:	ESP BOS (modifikation)	barrier width:	0.85 m (0.50 m)
performance data:	unknown (not tested)	barrier length:	2 x 100 m + length obstacle + Terminal
distance from roadside:	0,50 m	special design:	none
post distance:	4.0/2.0/1.0/0.5m		

construction layout: ESP BOS, modified for plane obstacles

other useful advice:

If the distance of the obstacle is < 1.0 m, the distance between barrier and roadside can be reduced upon at least 0.25 m.

In case of even smaller distances of < 0.75 m, the installation without the deformation elements is possible as an exception. This kind of change would cause a case of special design, which should only be chosen, if no other option is possible. Due to the missing deformation elements, here a higher ASI-value has to be expected (original test with ASI B).

Fig. 4 examples of fact sheets; (a) tree line; (b) pillar, counter bearing

After about two years working with the tree compendium the road administrations gave a very positive feedback regarding the helpful advices and descriptive examples. The aimed support to implement the 5-year safeguard programme was roundly confirmed. To complement the compendium with the experience made working with it so far, it is planned to update the document with the new findings and add new best practice examples if necessary.

3.2. Ideas to evaluate the performance characteristics of barrier systems for special-purpose solutions

The tree compendium is a first step to find the most suitable barrier solution for a difficult boundary condition using the constructions that are available today, particularly with regard on small rural roads. In a second step it would be worthwhile to have special constructions of tested safety barriers that cover most of the critical boundary conditions without having to make any adaption on-site. This would support the improvement of traffic safety, since the variation of existing barrier systems contains a certain risk due to missing knowledge about the remaining performance characteristics.

Therefore a concept is needed, that provides a standardised testing procedure for evaluating barrier constructions for special-purpose solutions and to make their performance characteristics comparable. As already mentioned above, frequently found examples for those special-purpose solutions are short safety barriers and curved safety barriers at intersections with access roads. The EN 1317 does not offer defined testing conditions for this kind of constructions yet, since they may show combined characteristics of a safety barrier a well as a terminal or a crash cushion. Therefore it is not clearly regulated which part of the EN 1317 is relevant for a type testing (also see section 2). To find a way for a valid approval for those kinds of special-purpose constructions, testing conditions and acceptance criteria should be defined which are to be based on the regulations of the EN 1317.

One idea is to combine the today defined testing conditions of safety barriers, crash cushions and terminals in an appropriate way that fits the characteristics of the special-purpose construction. The advantage of using the testing conditions of the existing European regulations lies in the then nearly comparable testing level like other road restraint systems. In addition the existing testing setups (e.g. testing facilities, vehicles, measurement instrumentation) could be used, so that the effort compared to the familiar tests is similar.

Since the demand on curved barrier systems in Germany has grown due to the safeguard program, the idea was born to develop a first draft of a testing and evaluating setup for those special-purpose constructions. Here various options for the combination of vehicle mass, velocity and impact angle are possible. A sketch of possible testing scenarios is shown in Fig. 5. Some important aspects and considerations made so far are described in the following.

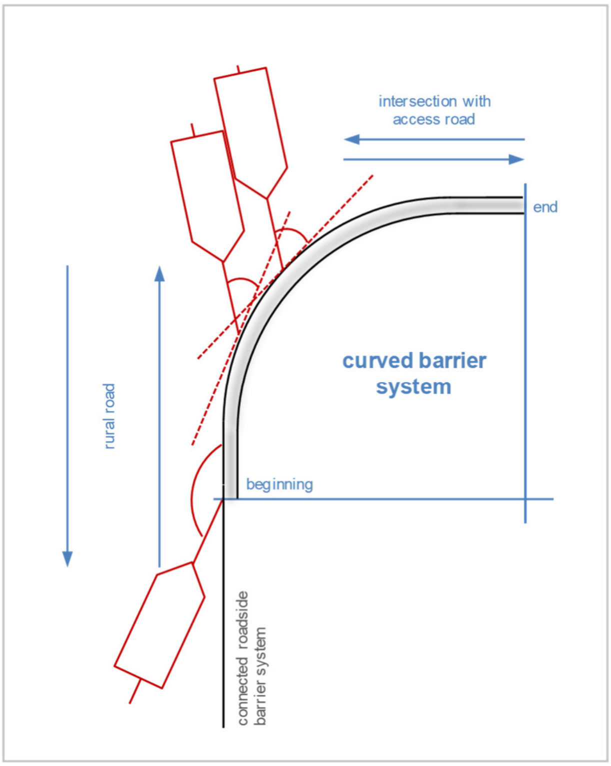


Fig. 5 sketch of testing scenarios for curved barrier systems

Leading for the considerations about appropriate and suitable testing conditions was the idea to aim at similar energies of the vehicle impact like they are required for barrier systems usually installed at rural roads in Germany (containment level N2 and H1). Table 1 shows the corresponding values of the impact energies comparing those of the official type tests according to the EN1317, Part 2 (TB 11, TB 32, TB 42, TB 51) as well as Part 3 (TC 2.1.80, TC 1.2.100) with the possible scenarios for the curved barriers.

Table 1. impact energies according to vehicle mass, velocity and impact angle

Test description	vehicle mass M (*kg*)	velocity V (km/h)	impact angle degree (°)	impact energy kilojoule (kJ)
TB 11	900	100	20	41
TB 32 (N2)	1500	110	20	82
TB 42 (H1)	10000	70	15	127

TB 51 (H2)	13000	70	20	287
Scenario 1	900	80	55	149
Scenario 2	900	100	40	143
Scenario 3	1300	60	55	121
Scenario 4	1300	80	55	215
Scenario 5	1500	80	40	153
Scenario 6	1500	100	40	239
TT 2.1.80	900	80	90	222
TT 1.2.100	1300	100	90	502

Another important issue for the drafting of test scenarios is the intention of using realistic accident situations of deviating vehicles from the road. Here deviating angels between 15° and 20° degrees seem to be suitable, since these values are also used in the EN 1317, Part 2 for the type testing of roadside barriers. Assuming this range of deviating angels the impact angels on the curved barrier varies between 15° and 90° degrees depending on the road width and the impact point location (see Fig. 5).

Further considerations should deal with the fact, that the boundary conditions on-site often show slopes directly behind the barrier which might degrade the performance of the curved barrier. In addition the scope of the variation of the radius of the curved barrier which should be covered by the tests has to be declared. Also the safe link to the connected roadside barrier has to be ensured. These are only few examples of aspects to be considered when developing appropriate testing conditions and evaluating methods for curved barriers. The above made descriptions can be used for a first impulse to deepen this topic.

To implement those ideas into the European regulations is one option to get a general basis for those approval procedures. Another idea, which might be realized a bit faster, is the way of developing an European Assessment Document (EAD), which has to be adopted in cooperation with the manufacturer, the TABs acting jointly in EOTA (Organisation for Technical Assessment), and the European Commission, see EOTA (2019). An EAD can be developed in all cases where the assessment of a construction product is not or not fully covered by a harmonised technical specification (here the EN1317), see EOTA (2019). If this can be a realistic a successful path for the future the legal framework has to be verified first.

However, these options would take some time and do not solve the challenges of today. That is why the German road authorities are dependent on using the tree compendium and their own experience when implementing the safeguard program. The here made experience can deliver an important input for future European regulations.

4. Conclusion and prospects

The tree compendium offers an appropriate tool for the road authorities for realizing the national safeguard programme in areas with restricted boundary conditions. Its success was confirmed during the last two years of practice. Not only the road authorities but also the engineering consultants work with the compendium which supports the planning and construction of uniform solutions on rural roads throughout Germany.

Nevertheless further procedural guidelines are needed, that provide a standardised procedure for evaluating barrier constructions for special-purpose solutions. One possible option was depicted in this paper and should be expedited in the following years based on the experience made so far. A generalized European regulation would not only support and strengthen the road authorities in their decisions to choose suitable and safe constructions for each situation on-site but also deliver precise specifications for the manufacturers which are supposed to promote the further development of barrier constructions for special-purpose solutions.

If manufacturers realize the demand of these constructions and the corresponding type testing is regulated in a verified standard the variety of available and safe barrier systems for special-purpose solutions is expected to grow quickly. This effect was already proven during the last twenty years of the existing EN 1317 since the development and variety of roadside safety barriers increased strongly. This way would offer an important component to continue the safeguard programme on rural roads not only in Germany and therefore would deliver an essential contribution to get one step further to the vision zero in Europe.

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