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# PROCEEDR - Optimizing Resources for more Sustainable Noise and Safety Barriers on European Roads

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**Abstract**

PROCEEDR aims to create tools to enable National Road Administrations to identify innovative and sustainable solutions to facilitate the transition from linear to circular economy in the field of roadside infrastructure. At the same time, high functional demand and technical performance requirements still need to be met. Therefore, the scope of PROCEEDR is to gather an overview of innovative and sustainable solutions with focus on noise and safety barriers, as well as to provide tools for selecting the most suitable and cost-effective solutions. The paper gives a general overview of the project goals and the methodology to be used, showing also the first activities performed. More detailed results will be presented at the conference in November 2022, while other project results will be presented in the frame of upcoming conferences.



*Keywords:* Sustainable cities and communities; circular economy; traffic noise and vibrations mitigation; health and quality of life.

## 1. Introduction

### *1.1. Background and research needs*

The PROCEEDR project aims to create tools to enable National Road Administrations (NRAs) to identify innovative and sustainable solutions to facilitate the transition from linear to a circular economy in the field of roadside infrastructure. Achieving a circular economy requires minimizing the demand for primary resources and reutilizing resources in high-value applications. NRAs need a wider range of material options to change from linear to circular economy. At the same time, high functional demand and technical performance requirements still need to be met (e.g., safety, acoustic, structural, maintenance, etc.). New innovative and sustainable options could be bio-based, renewable

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resources (such as wood or composites with natural fibers) and the use of recycled/recyclable materials. Therefore, the scope of the project is to gather an overview of innovative and sustainable solutions in the roadside infrastructure sector, noise and safety barriers and provide relevant tools for selection of most suitable and cost-effective solutions.

The roadside infrastructure is today equipped with various devices having a relevant impact on the total amount of materials used for road construction. In the last decades, the number of products used alongside roads has been widely increased. At the same time, the road infrastructure accounts for extensive use of natural resources and it is a major generator of the waste as well as comprises assets with a lifespan of up to 100 years. Therefore, the National Road Authorities decided to take a lead and encourage the proper handling of scarce materials. Moreover, NRAs have developed procedures and tools to assess the environmental or even sustainability performance of construction projects. Hence, there is an incentive for suppliers of roadside materials to optimize their products according to the requirements demanded and criteria assessed by these tools.

To become more material-efficient, NRAs must recycle/reuse materials and use more renewable and biodegradable materials. Among road equipment's, noise barriers and safety barriers are the most relevant ones. Hence, these product types were selected as study objects of the present research.

### *1.2. Noise barriers and safety barriers as main subject of PROCEEDR*

**Noise barriers** are a very relevant asset in road infrastructure for this research project because they are made of a large variety of materials and solutions which varies from the most classical options (wood, concrete, or metallic cassettes) to the most innovative ones (e.g., cassettes in recycled PVC, sound-absorbing natural fibers, etc.). The assessment of technical performance is based on tests and calculations according to the product standard EN 14388:2015 where acoustic, structural, safety, fire and durability characteristics are considered. Noise barriers will also offer the chance to explore innovative solutions for foundation works which are always required for the installation alongside roads. Roughly one-third of the total economic value of the noise barrier is represented by foundation works and alternative solutions, such as ground screws or metallic poles hammered into the ground, can be used instead of concrete kerb and ground cementation.

Nowadays, performance of **safety barriers** is assessed according to crash tests of different vehicle types according to the product standard EN 1317-5:2013. Given the high technical constraints to achieve minimum levels of performance required, the use of other materials than steel or concrete has been rarely considered. Timber can be used for safety barriers installed alongside rural roads where lower containment levels are required. Furthermore, for the scope of the present research, considering safety barriers allow us to evaluate the impact of additional materials used for improving the behaviour of steel or concrete on sustainability. Even a limited improvement achieved by using new materials and/or improving the corresponding industrial processes may lead to a significant impact on the overall sustainability of road infrastructures given the extended use of safety barriers alongside roads, given that the functional properties are assured.

For example, the use of pre-galvanized steel instead of batch galvanized steel for guard rails can significatively impact in the production chain (see Figure 1). Also, to be considered that safety barriers are part of the family of road restraint systems (i.e., impact attenuators, transitions, terminals, …). For some of these products, investigation on new sustainable materials can be foreseen.

Assessing sustainability of safety barriers will be extended to the life stages after the production. The software-tool being developed within this project will allow comparison between different installation methods or even direct manufacturing of the product on site. This is the case of the new-jersey safety barriers that can either be cast in situ or manufactured in the factory and transported to the installation site.

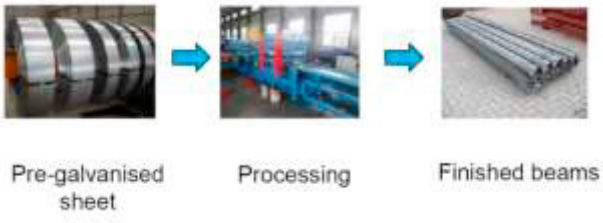


Fig. 1. Example of an improved industrial process using pre-galvanized steel (bottom) instead of batch galvanized steel for guard rails (top).

Having referred to noise and safety barriers, special attention will also be given to some peculiar products where both functions are integrated and placed on the market as a unique system. Figure 2 shows exemplary two integrated barriers, integrating different functional requirements for being used as noise and safety barrier at the same time.

Fig. 2. Different types of integrated noise and safety barriers of different materials in Europe (steel & transparent left side and fully concrete type right side).

These products show more functional constraints as it needs to fulfil requirements set for the two separate systems, but it may perform better in terms of sustainability given the chance offered for saving additional structures on bridges or reducing land use when installed on the ground.

When using an integrated system alongside roads the expected output is the reduction of the total height of the noise barrier thus maintaining the same acoustic result. This also may have an added value in terms of impact on landscape (as the acceptance by the inhabitants should be considered a relevant social aspect). The tools being developed within the present project shall be able to measure those expected added values of the integrated system.

## 2. Sustainability approach in the European context

Nowadays, the current dimension and the complexity of noise barrier and safety barrier projects confirm the need to apply the concept of sustainability for relevant construction work as well as for resources required to product, install, maintain, monitor and finally - if needed - to remove noise barriers once they have reached the end of their life cycle. This makes evident that noise and safety barrier projects involve many resources (not only of the environmental type) and have in general a very high impact on the built environment as any other large built structure.

In general, the assessment of sustainability should be based on an environmental life cycle approach taking into consideration cradle-to-cradle impacts, including resource impacts, long-term environmental performance (maintenance) and end of life (decommissioning).

Social aspects should also be considered. I.e., transparency in the noise barrier is generally preferred by residentials as it helps to minimize the impact on the landscape; again, for noise barriers some materials are preferred to minimize heat island effect in the screened zone.

To assure a holistic life cycle engineering approach the list of relevant aspects should be completed by adding different functionalities: security of supply, adaptability, lifespan extension options, high value recycling/reuse options, carbon capture capacity. Finally, noise barriers cost, and other economic indicators should be considered.

Given this framework technical and functional aspects represent the basis for further analysis of any possible overall sustainability assessment of a noise barrier, based on the calculation and/or measurements of (1) environmental, (2) social and (3) economic indicators.

The need for a Life Cycle Analysis (LCA) for noise barriers is also made evident by the large variety of materials and solutions (to some extent already in use) which varies from the most classical options (wood, concrete, or metallic cassettes) to the most innovative ones (e.g., cassettes in recycled PVC, sound absorbing natural fibers, ...). Moreover, innovative solutions for foundation works should be also considered. Roughly one third of the total economic value of the noise barrier is represented by foundation works and alternative solutions, such as ground screws or metallic poles hammered (respectively filled) into the ground, can be used instead of concrete curb and ground cementation. The terrain remains untouched, there is no soil sealing and the overall logistical effort is reduced.

### *2.1. Sustainability and Green Public Procurement*

Europe's National Road Authorities (NRAs), which are in some case public bodies and in other cases private companies, are the major end users, beneficials and operators of noise and safety barriers. This increases the need for noise barrier's sustainability to be considered by all policy makers and all other relevant stakeholder involved in the process, to be in line with a growing sustainable agenda for surface transport and its respective infrastructure. This need is covered by the European legislation on Green Public Procurement (GPP) as green purchasing criteria for Road Design, Construction and Maintenance, has been published (EU Communication (2016)).

Although GPP is a voluntary instrument, it has a key role to play in the EU's efforts to become a more resource-efficient economy and is a strong stimulus for innovation and for a more sustainable market, therefore the GPP criteria been applied more and more during the last years.

During the last decade technical standards are also being developed to provide methods and criteria for supporting manufacturers when assessing NB sustainability before placing the product on the European market. These standards must be considered within the scheme of technical standards used for drafting the Declaration of Performance (DoP) and applying the CE marking to noise barriers according to CPR (EU Regulation 305/2011 (2011)).

Finally, a general scheme for all construction works is offered by the standard EN 15804:2019, where a set of indicators is provided to assess sustainability over the entire life cycle.

The results of the research project QUIESST (EU project QUIESST (2012) represent the first step into the topic of sustainability for the noise barrier sector. Information's can be drawn about a holistic approach to sustainability also including all evaluation criteria of the environmental, technical, social, and economic aspects. PROCEEDR will go beyond these results also delivering practical tools for NRAs (PROCEEDR website (2021)).

## 3. Environmental life cycle approach in PROCEEDR

In general, the assessment of the application of such solutions should be based on an environmental life cycle approach taking into consideration cradle-to-cradle impacts, including resource impacts, long-term environmental performance (maintenance) and end of life (decommissioning). To assure a holistic life cycle engineering approach a lean Life Cycle Cost Assessment (LCCA) and Social Life Cycle Analysis (SLCA) will be applied. The relevant aspects that will be considered are (i) the technical requirements (e.g., safety, acoustic and non-acoustic performance), (ii) durability, (iii) maintenance, (iv) costs and (v) different functionalities. In addition to that, security of supply, adaptability, lifespan extension options, high value recycling/reuse options, carbon capture capacity should also be considered. At this point it is relevant to note that the present project is focused on "products" and not on "construction sites". Therefore, the aspects related to site-dependency will not be considered in this assessment. This choice may entirely exclude some social aspects related to the specific construction and the installation site.

Nevertheless, relevant products characteristics will be considered as they may have social consequences. I.e., transparency in the noise barrier is generally preferred by residentials as they minimize the impact on the landscape. Again, for noise barriers some materials are preferred to minimize heat island effect in the screened zone.

Safety barriers having a smooth rear side represents a safer solution when installed to protect bike paths next to the road. Therefore, the analysis of the overall sustainability of the products is based on technical aspects and involves environmental, social, and economic prerequisites (see Figure 3).

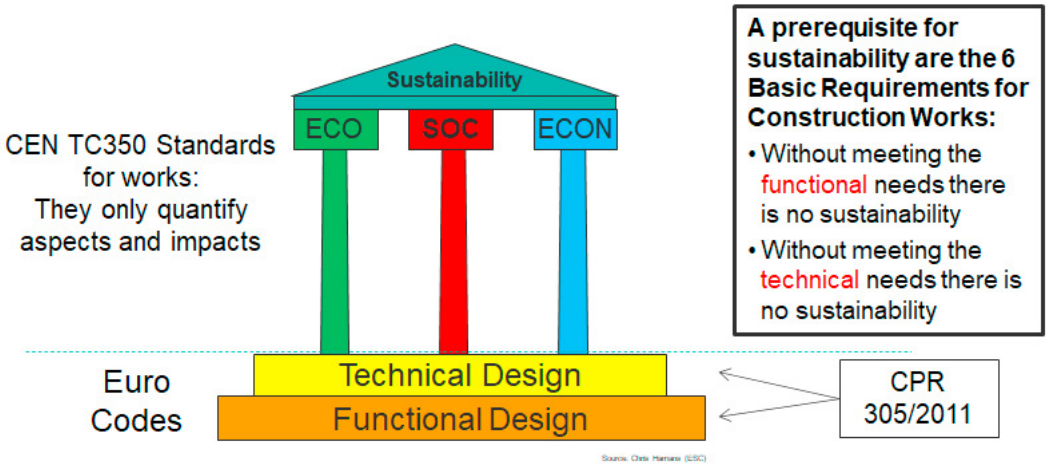


Fig. 3. Sustainability of construction works according to the standardization work of CEN/TC350 (Source: Chris Hamans, ESC, 2012).

Among the basic work requirements proposed by CPR for construction works, noise and safety barriers need to fulfil mechanical resistance, safety in case of fire, safety in use, noise protection, hygiene specifications for materials used. Sufficient level of performance with reference to the above requirements guarantees that the product meets functional and technical needs and represents the essential conditions for further investigations on a full set of Key Performance Indicators (KPIs) of the environmental, social, and economic for all different life stages. The Figure illustrates that the Technical and Functional Design are necessary to be assured before an assessment of the environmental, economic, and social performances can be regarded meaningful or to say it with other words, no sustainability can be achieved without a convincing Technical and Functional Design. These KPIs will be defined also with reference to previous research projects (e.g., the EU project QUIESST, SOPRANOISE, LC4Roads, etc.) and will be the base of further development of a methodology based on two different tools: (1) an online-tool with benchmark calibrated on existing system/products and used to evaluate innovative ones and (2) a second software-tool focusing on the overall sustainability assessment of a single system (or product).

## 4. PROCEEDR methodology and project structure

This section briefly explains the general methodology to be used in PROCEEDR, the project structure, and the main objectives for each work package (WP). Figure 4 presents a general overview of the project structure and the interconnections between the different work packages.

The project will combine several methods to achieve its goals. A comprehensive desk research will be applied to identify state-of-the-art roadside products/solutions commonly built within different European countries. This task will include studies on regulatory requirements and recent scientific publications and research project reports. The software development will apply a Rapid Application Development (RAD) process to quickly adjust to shifting requirements. A close collaboration with the main target group, the NRAs, will be enabled by personal interviews at the most relevant stages within the project. The stakeholder interaction will be complemented by a webinar with important suppliers from the industry sector and NRAs.

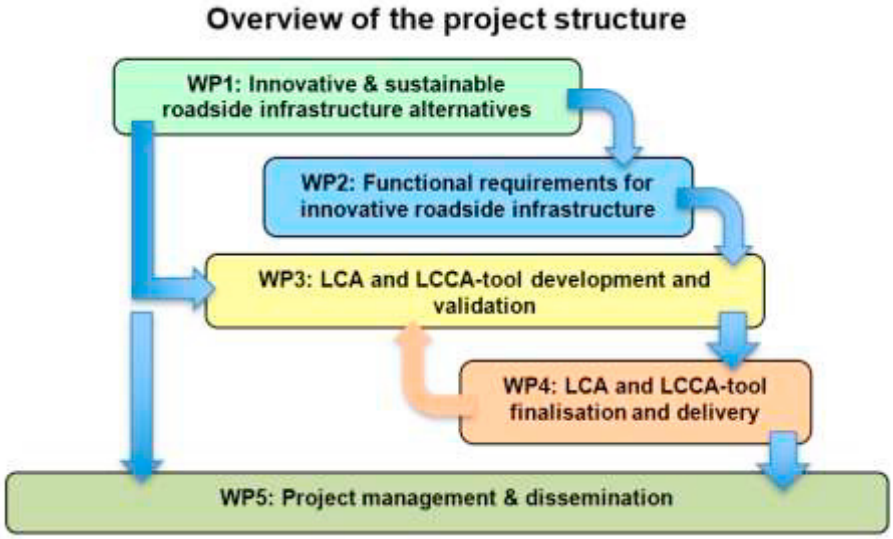


Fig. 4. Project structure and interconnections between the different work packages.

WP1 will perform first a state-of-the-art survey on roadside infrastructure materials mainly in the noise and safety barrier sectors, collecting a relevant number of different use cases from manufacturers, industry associations, NRAs and CEDR members with special focus on innovative solutions. The information will be collected throughout Europe using a dedicated online questionnaire. In addition, data and information collected in past and current projects like SOPRANOISE, QUIESST, QUESTIM, LCA4Roads will be considered. Based on this literature review, the research gaps will be identified, paying special attention to durability issues.

Furthermore, a standardized methodological approach in combination with ranking criteria for selection of sustainable and innovative roadside infrastructure will be developed, in order to identify a suitable classification for various types of noise and safety barriers. After that, a selection of a relevant number of application cases will be analyzed in more detail. Within these selected application cases, standard as well as innovative solutions will be considered for further evaluation with the tools to be developed in WP3 and WP4. The application cases will be evaluated in respect to their acoustic performance (EN 1793-n), non-acoustic properties (EN 1794-n and EN 14388) as well as regarding possible Environmental Product Declaration (EPD) and/or sustainability according to EN 15804 and the draft standard EN 17383 (currently in preparation by CEN/TC226/WG6). As a final output a practical guideline for assessing the use of different material in roadside infrastructure products will be provided.

WP2 will summarize and evaluate the functional and technical requirements of the considered products (i.e., noise barriers, safety barriers and integrated barriers) with special focus on innovative solutions like bio-based and natural fibers, composites and/or recycled and recyclable or renewable material solutions. Advantages and limitations of the solutions will be highlighted, considering not only the production and construction phase but focusing on the procurement phase. The environmental and weather conditions present in the funding countries (i.e., Sweden and UK) will be considered in more detail. The work within this WP will involve close consultation with European NRAs and industry to gather detailed data and information about the processes on using innovative roadside infrastructure solutions across all life cycle phases. Based on the summarized technical and functional requirements, WP will define a set of reasonable and representative assumptions related to the use of selected roadside infrastructure solutions and materials. These assumptions will feed into the WP3-WP4 work on the development of an online tool for material/solution benchmarking and modelling/assessing resource efficiency.

WP3 and WP4 will build upon the output of WP1 and WP2. The objective of the work is to develop (i) an online-tool for comparative study on costs and benefits and total life cycle with special focus on comparing different solutions and (ii) a software-tool to model and assess resource efficiency and circularity, analyzing in more detail one single solution regarding functional and technical requirements as well as sustainability aspects, considering all relevant KPIs identified. Both tools are based on the data collected during the project and the KPIs identified previously. A

systematic approach combining (Multi) LCA and LCC assessment for different applications, considering the different environmental conditions of the funding CEDR member countries (i.e., Sweden and UK) will be applied.

WP5 will effectively disseminate the project´s results to the NRAs and manage the overall project in close collaboration with the Project Executive Board (PEB) established by CEDR. A dedicated website (already active) will be used to promote the outcomes of this project to NRAs, other stakeholders of the industrial sector, the scientific research community and the wider public.

## 5. First activities on innovative and sustainable roadside infrastructure alternatives

PROCEEDR officially started in November 2021 with the activities of WP1 on innovative and sustainable roadside infrastructure alternatives. After a first literature review the main actors and producers have been identified. Therefore, it was decided to develop two different online surveys, to get direct in contact with the relevant stakeholders: (1) first a questionnaire with special focus on NRAs has been developed; (2) in parallel a second questionnaire was developed having the industry sector as a main target: in this case the questions were more focused on manufacturers, producers, and contractors. Both questionnaires have been circulated from November to March 2022. The data analysis has started in April and is still work in progress, so that at this time only a quick overview of the questions sent, and the number of replies can be shown at this moment in this paper. The authors are planning to show these results at the TRA conference. Nevertheless, to get a first impression of the issue requested in the surveys it is relevant to show the requested issues. The survey for NRAs hast investigated the following points:

- Are you using Key Performance Indicators (KPIs) to assess the performance of the construction work/services provided by your contractors (over the full life cycle)?
- Have you already (co-)developed or are you planning to develop IT-supported tools and/or databases to assess the economic, environmental and/or sustainability performance of construction works/services that you are commissioning (including bidding processes)?
- If you are using apply IT-supported tools and/or databases to assess the economic, environmental and/or sustainability performance of construction works/services in your daily practice, what are your experiences so far? What is working well and where have you experienced challenges?
- How would you define innovative (sustainable) roadside equipment? Are you aware of good practices for innovative and sustainable roadside equipment?
- Are you aware of research projects (ongoing or finished) that have dealt with innovative and sustainable roadside equipment?

Regarding the questionnaire for industry stakeholders the following information have been requested:

- In which kind of road equipment are you interested (safety barriers, noise barriers, both, other)?
- Is your company familiar with schemes used to assess environmental sustainability of the whole construction process e.g., LEED, BREEAM, DGNB/ÖGNI or specifically for road infrastructure (i.e., Envision, CEEQUAL etc.)?
- Have you considered (if not yet implemented) implementing environmental declaration (i.e., EPD according to ISO 14025) or alternative Life Cycle Assessment (LCA) based information to communicate the environmental performance of your products?
- Have you ever been asked to provide environmental sustainability criteria in bidding processes/evaluation in the product/service procurement phase?
- Can you indicate the type of equipment your company produces / installs?
- With reference to the products your company produces / installs, do you foresee any future actions to improve the environmental sustainability performance of the raw materials used?
- With reference to the products your company produces / installs, do you see possible actions / measures to improve the environmental performance in the manufacturing / installation / the maintenance / decommissioning phase? We would be grateful if you could provide further technical details (e.g., types of materials used, weight of the materials, estimated service life, etc.) about your products/solutions.

Finally, a total of 114 different companies have been approached by the online survey and 48 of them replied positively. The companies are based in the following countries: Sweden, Norway, Austria, UK, France, Poland, Italy, Luxembourg, Germany, The Netherlands, Spain, Croatia, Belgium, so that 13 different European countries are represented in the results.

## 6. Outlook and future work

The detailed results of both surveys will be presented at the TRA conference in November 2022 and will also include an overview of the relevant use cases identified. Other main outputs of PROCEEDR will be presented at further conferences, these results will include the following: (i) State-of-the-art review to identify research gaps on durability of sustainable and innovative products; (ii) practical guideline based on the evaluation of the use cases, including recommendations for industrial stakeholders on how to provide data for further sustainability assessment requested by NRAs; (iii) online tool for a comparative study on costs and benefits and total life cycle – and where possible on other harmonized indicators (e.g. economic and social impacts) (iv) a software tool to model and assess resource efficiency (for example on climate change), when using the suggested materials for the specific applications; (v) a final report providing practical recommendations for NRAs how to implement sustainability policy by using the developed tools.

## Acknowledgements

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## References

EU Communication (2016). EU Green Public Procurement Criteria for Road Design, Construction and Maintenance, Brussels, 2016

EU Regulation 305/2011 (2011), the European Parliament and of the Council of 9 March 2011 laying down harmonized conditions for the marketing of construction products and repealing Council Directive 89/106/EEC Text with EEA relevance

EU project QUIESST (2012) “QUIetening the Environment for a Sustainable Surface Transport”, FP7 program

PROCEEDR website (2021): https://proceedr.project.cedr.eu/