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PROCEEDR
OPTIMISING RESOURCE USE FOR ROADSIDE INFRASTRUCTURES

Sustainability of roadside infrastructure equipment

State-of-the-art report

Deliverable D1.2 (including Milestone M1.2)

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CEDR TRANSNATIONAL RESEARCH PROGRAMME

Call 2020: Resource Efficiency and the Circular Economy

PROCEEDR

OPTIMISING RESOURCE USE
FOR ROADSIDE INFRASTRUCTURES

D1.2 State-of-the-art report on sustainability of roadside infrastructure equipment

M1.2: Selection of relevant roadside infrastructure solutions and methodology or ranking criteria for product selection

Work package / task: WP1 / task 1.2

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Executive summary

The main goal of this document is to build the basis for the future work to be done in PROCEEDR together with the first deliverable D1.1 on existing LCA/LCCA-tools and roadside infrastructure solutions including a SWOT analysis of existing tools.

The main scope of work package WP1 is to perform 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 was collected throughout Europe using a dedicated online questionnaire, achieved with in M1.1 (Questionnaire and interviews with relevant stakeholders carried out). In addition, data and information collected in past and current projects were considered.

Furthermore, ranking criteria for selection of sustainable and innovative roadside infrastructure will be developed, 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 analysed 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 present document is structure as follow: in Chapter 1 a first general introduction is given, where the research needs and the aim of PROCEEDR, the specific objectives of WP1 and the approach on sustainability are explained with focus on noise and safety barriers.

Chapter 2 describes the status of the European regulations and the current sustainability approach in the field of noise and safety barriers, answering to the question “how the environmental and sustainability topics have been dealt within past and current construction projects in the field of nose and safety barriers.

Chapter 3 gives an overview of the noise and safety barrier types commonly used in Europe and suggest a tentative classification for the most used noise and safety barrier types in Europe. A schematic template for inserting relevant information on the whole life cycle has been developed and for every noise and safety barrier type the template was filled.

In Chapter 4 the development of the survey, the results of the survey and a statistical analysis of the survey for industry stakeholders is shown. Based on these results the selection of relevant roadside infrastructure solutions is performed and described in Chapter 5, which means the achievement of Milestone M1.2 (Selection of relevant roadside infrastructure solutions and methodology or ranking criteria for product selection).

Finally, the last Chapter 6 is building the bridge to the last activities of WP1, which will conclude in report D1.3 “Practical guideline with a recommendation for industrial stakeholders to assess the use of different materials in roadside infrastructure”.

“This project has received funding from the CEDR TRANSNATIONAL ROAD RESEARCH PROGRAMME Call 2020Resource Efficiency and the Circular Economy”

1 Introduction

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.

1.1 Research needs and PROCEEDR´s aim

The National Road Authorities (NRAs) decided to take a lead and encourage the proper handling of materials, which are less and less available on the market. Moreover, NRAs have already 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 resource-efficient, **NRAs must encourage utilization of 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.

The PROCEEDR project aims to create two **tools** to enable 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 minimising 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 resources (such as wood or composites with natural fibres) 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, focusing on noise and safety barriers** and provide relevant tools for selection of most suitable and cost-effective solutions.

1.2 Noise and safety barriers as PROCEEDR´s focus

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 fibres, reed, loam, etc.). The assessment of technical performance is based on tests and calculations according to the product standard EN 14388 where acoustic, structural, safety, fire and durability characteristics are considered.

Noise barriers are 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. 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.

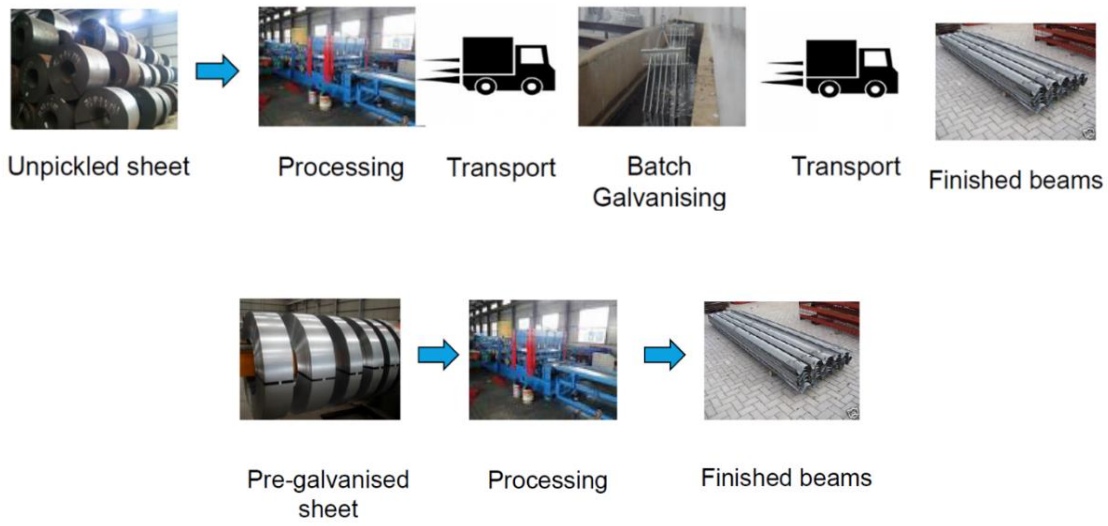


Figure 1: Example of an improved industrial process using pre-galvanized steel (bottom) instead of batch galvanized steel for guard rails (top).

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.** 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.

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

1.3 The PROCEEDR approach

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, transport, and installation stage, as well as long-term environmental performance, maintenance, and end of life (also called decommissioning stage).

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; or some materials for the noise barriers 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 the following parameters:

- **environmental impact**
- **social impact**
- **economic impact.**

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.

1.4 Objectives of work package 1

Work package 1 (WP1) has the scope to draft the state-of-the-art survey on roadside infrastructure equipment focusing on noise and safety barriers, collecting a relevant number of different use cases from manufacturers, industry associations, NRAs and CEDR members with special focus on innovative solutions. The information has been collected throughout Europe due to a dedicated online questionnaire. In addition, data and information collected in past and current projects (e.g., SOPRANOISE, QUIESST, QUESTIM, LCA4Roads) were considered.

A suitable classification for various types of noise and safety barriers was derived from previous research activities and already is used in different projects. Furthermore, a selection of sustainable and innovative roadside infrastructure was collected for the further scope of PROCEEDR. The selected ‘use cases’ were analysed in more detail. Within these selected application cases, standard solutions as well as innovative solutions will be considered for further evaluation by the tools to be developed in WP3 and WP4.

The selected 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/TC 226/WG 6).

As a final output of WP1 a practical guideline for the technical assessment and the use of different material in roadside infrastructure products, which will be provided in report D1.3.

2 European regulations and current sustainability approach in the field of noise and safety barriers

The present chapter describes in more detail the European regulations and the state of the art on sustainability, with reference to noise and safety barriers. The following questions are addressed:

- How are currently regulated noise and safety barriers in Europe?
- Which kind of standards, directives and regulations are available and how their implementation and applicability are performed?
- How the topic of sustainability has been dealt within current and past design in construction of the noise and safety barriers?
- How the topic of sustainability has been dealt within past and current research projects?

2.1 European regulations and standards dealing with noise and safety barriers

In Europe construction products are regulated by the so-called **CPR** (Construction Products Regulation)[1] that governs their **introduction into the common market**.

According to the CPR, manufacturers, or their representatives, are requested to declare and guarantee the performance of road equipment's according to a **common set of technical standards** developed by technical commissions established within CEN[2].

The **product performance is declared** for the so-called **essential characteristics** of the road construction, which are listed in CPR as following ones:

(i) Mechanical resistance and stability

(ii) Safety in case of fire

(iii) Hygiene, health, and the environment

(iv) Safety and accessibility in use

(v) Protection against noise

(vi) Energy economy and heat retention

(vii) Sustainable use of natural resources.

By affixing the **CE marking** the manufacturer attests the **conformity of the construction product with the declared performances in relation to the essential characteristics**, covered by the harmonised standard or by the European Technical Assessment which relates to the construction product.

[1] CPR Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products.

[2] CEN TC 226 Road Equipment WG6 Anti-Noise Devices.

CE marking indicates to the appropriate bodies that **the product may be legally offered for sale** in their country and gives companies easier access into the European market to sell their products without adaptation or rechecking.

For Road Equipment's the **technical Committee CEN/TC 226** is working under a specific Mandate of the EU Commission, and several working groups (WGs) have been activated to deal with different type of products.

With reference to the products that are considered within the present research work (safety barriers and noise barriers) **WG 1 *Road restraint systems* and WG 6 *Anti-noise devices*** are the working groups drafting the standards published by CEN.

The Mandate issued by the Commission is referred to the essential characteristics 4 (Safety in use) and 5 (Protection against Noise). This means that the manufacturer, when placing the product on the common market, is requested to declare the performance of the product according to these characteristics.

The following product standards governing the **procedure of CE marking have been developed a harmonized:**

- **hEN 14388:2005** Road traffic noise reducing devices – Specifications.
- **hEN 1317-5:2012** Road restraint systems — Part 5: Product requirements and evaluation of conformity for vehicle restraint systems.

NOTE: within the present document the wording:

- **noise barrier** will be used with the same meaning of road traffic noise reducing devices (RTNRD), the wording NRD commonly used in the standardisation process of CEN, while noise barrier is more used in the manufacturers and tendering speech.
- **safety barrier** will be used with the same meaning of road restraint systems (RRS).

2.1.1 European standards on noise barriers

The following European standards provide **methods for testing or calculating the performance on a product sample of noise barrier**:

- EN 1793-1:2020, Road traffic noise reducing devices - Test method for determining the acoustic performance – Part 1: Intrinsic characteristics of sound absorption under diffuse sound field conditions.
- EN 1793-2:2020, Road traffic noise reducing devices - Test method for determining the acoustic performance – Part 2: Intrinsic characteristics of airborne sound insulation under diffuse sound field conditions.
- EN 1793-4:2020, Road traffic noise reducing devices - Test method for determining the acoustic performance – Part 4: Intrinsic characteristics - In situ values of sound diffraction.
- EN 1793-5:2020, Road traffic noise reducing devices - Test method for determining the acoustic performance – Part 5: Intrinsic characteristics - In situ values of sound absorption under direct sound field conditions.
- EN 1793-6:2020, Road traffic noise reducing devices - Test method for determining the acoustic performance – Part 6: Intrinsic characteristics - In situ values of airborne sound insulation under direct sound field conditions.

- EN 1794-1:2020, Road traffic noise reducing devices - non-acoustic performance – Part 1: Mechanical performance and stability requirements.
- EN 1794-2:2020, Road traffic noise reducing devices - non-acoustic performance – Part 2: General safety and environmental requirements.
- EN 14389-1:2020, Road traffic noise reducing devices - Procedures for assessing long term performance – Part 1: Acoustical characteristics.
- EN 14389-2:2020, Road traffic noise reducing devices - Procedures for assessing long term performance – Part 2: Non-acoustical characteristics.
- EN 14388:2005 Road Traffic Noise Reducing Devices – Specifications.

2.1.2 European standards on safety barriers

The following standards provide methods for testing or calculating the performance on a product sample of safety barrier; EN1317 is divided into different parts, each of which takes care of a different aspects or a different kind of product:

- EN 1317-1, Road restraint systems - Part 1: Terminology and general criteria for test methods
- EN 1317-2:2010, Road restraint systems - Part 2: Performance classes, impact test acceptance criteria and test methods for safety barriers including vehicle parapets
- EN 1317-3:2010, Road restraint systems - Part 3: Performance classes, impact test acceptance criteria and test methods for crash cushions
- EN 1317-5:2007+A2:2012 Road restraint systems Part 5: Product requirements and evaluation of conformity for vehicle restraint systems
- EN 16303: 2020 Road restraint systems validation and verification process for the use of virtual testing in crash testing against vehicle restraint system
- XP CEN/TS 17342: Road restraint systems - Motorcycle Road restraint systems which reduce the impact severity of motorcyclist collision with safety barriers
- XP CEN/TS 16786: Road restraint systems - Truck Mounted Attenuators - Performance classes, impact test acceptance criteria and test performance

2.1.3 Common issues related to CPR implementation for noise and safety barriers

hEN also indicate the procedure that need to be followed to ensure the constancy of performance for the products placed on the market. Manufacturers are asked to implement a factory production control that may involve the **surveillance of a third party** (Notified Body).

For **safety barriers the Notified Body is periodically checking the FPC**[3] (meaning system 1 according to AVCP[4] in the wording of the CPR). Instead, **noise barriers production is entirely under the control of the manufacturers** (meaning system 3 according to AVCP).

In the last decade difficulties have been encountered by manufactures and laboratories as many technical standards are not updated and alignment is missing between references provided by the product standards and the content of technical standards.

[3] FPC: Factory Production Control (FPC) is the permanent control of production exercised by the manufacturer.
[4] AVCP: Assessment and Verification of Constancy of Performance.

For example, in the case of noise barriers the product standard hEN 14388:2005 has not been aligned to the updated versions of the technical standards EN 1793-n, EN 1794-n, EN 14389-n published in the last decade. Therefore, some issues on the market often emerge.

For safety barriers the valid hEN 1317-5 has been published in 2012 and it has not been updated and no official version of the standard have been published on the Official Journal (OJEU).

The situation is leading to a profound **revision of the CPR**. The draft document circulated by the Commission is revealing the intention of setting a **clear distinction between technical supporting standards developed by CEN** and the **product standards under the control of the Commission.**

The aim is that of strengthening the process of creation of a common market of construction products in Europe while National Authorities remain entirely responsible of setting threshold levels for product performance and the rules for their installation, use and maintenance.

Need to be remarked that **CPR is not governing the installation phase, the maintenance and the procedure for dismantling, recycling, or reusing the construction products when the end of life is reached**. Those phases fall out of the perimeter of the harmonization (common law) and remain entirely under the control of National Authorities.

Also, **threshold values for the product characteristics are defined at a national level**.

E.g., the **different national legislations** are then defining noise levels at residentials to be achieved by installing a noise barrier.

Similarly roadside safety levels in case of errant vehicles, containment levels and the impact severity index of safety barriers maybe different from a country to another depending on different type of roads.

Another field of harmonization can be seen with reference to **design rules**. I.e., Eurocodes about structural calculation and design rules for the main construction materials. Also, acoustic modelling of noise emitted by road traffic[5].

Because of the above reasons for noise and safety barriers differences in various EU countries remain profound as regard as statal budget type of products used, level of performance requested, maintenance activities, frequency of substitutions and end of life management.

For safety barriers, in some countries National Authorities preferred a unique product (or set of products) with the aim of simplifying the procurement phase and maintenance activities.

In the countries where relevant road networks are managed by **private/public concessionaires**, product standardization has been carried on independently by each road manager.

In general, the product standardization for noise barriers cannot be fully implemented. Product adaptation to the site application is often required for acoustic and structural reasons, roadside conditions.

In some countries national specification have been published for a set of commonly used materials and products. This is the case of the guidelines ZTV Lsw 22[6] where specifications

5 Common noise assessment methods in Europe (CNOSSOS-EU) to be used by the EU Member States for strategic noise mapping following adoption as specified in the Environmental Noise Directive 2002/49/EC.

6 ZTV Lsw 22 - Zusätzliche Technische Vertragsbedingungen und Richtlinien für die Ausführung von Lärmschutzwänden an Straßen (*Additional Technical Conditions Contract conditions and guidelines for the construction of noise barriers on roads*).

are given for the main product currently used to realize for noise barrier alongside German roads. Such documents represent a reference for designer it happens that only a few special projects fall out of the perimeter of the national guideline.

It is also to be remarked that noise barriers have been implemented extensively only for new roads where the acoustic impact has been considered among the general evaluation of the environmental impact assessment.

For **existing infrastructures**, the European legislation[7] has given a contribute with the **harmonization of noise mapping** activities and the preparation of action plan by Road managers. The implementation of the action plan by mean of various measures, noise barriers included, remains under the exclusive control of Member States.

2.2 Current implementation of environmental and sustainability topics in construction projects

In this chapter the Green Public Procurement (GPP) will be described. Furthermore, the regulation and draft proposal for standards concerning application of GPP for noise and safety barriers will be presented. Finally, the results of the previous research will be merged by the approach of 'Geek temple' suggested by PROCEEDR.

2.2.1 The Green Public Procurement (GPP)

An impulse to the harmonization process of rules governing sustainability of construction products in Europe is provided by the **Green Public Procurement (GPP)** criteria and its legal framework Public Procurement Directive 2014/24/EC.

The EU website on GPP[8] contains recommendations (the so-called GPP Criteria) on how to include **environmental/sustainability criteria in public tenders** for different domains.

Recognising the challenge to provide more benefits to current and future generations, the road infrastructure sector has steadily taken steps to embrace environmental objectives. It has constantly **developed on a voluntary** basis new solution that both make greater use of existing materials through recycling and, at the same time, have generated new technologies for construction processes able to extend the durability of the road network and reduce the use of virgin materials. In this regard, the road infrastructure sector is actively working to prolong the life cycle of the network and reduce the need for frequent maintenance interventions that automatically generate important benefits in terms of **energy savings, noise reduction, CO2 emissions or the use of raw materials** linked to road construction and maintenance operations.

The directive seeks to modernise the whole framework for public procurement to allow governments to adapt their tendering processes to current needs to facilitate acquisition of greener and more innovative products and services. In addition, an updated set of rules will also permit to address new challenges (i.e., climate change, connectivity, limitation of natural resources, globalization, etc.).

By encouraging public authorities to **modify the philosophy of the purchasing approach**, it provides at the same time incentives to industry to **invest in research and innovation**. The combination of these two elements will benefit the whole of society by optimising public resources and delivering to citizens better and more durable roads.

7 END European Noise Directive Directive 2002/49/EC

8 https://ec.europa.eu/environment/gpp/index_en.htm

The EU GPP criteria have been developed to facilitate the **inclusion of green requirements** in public tender documents. EU GPP criteria have been developed in different areas, amongst them "road Design, Construction and Maintenance".

Moreover, each Member state has been encouraged to draw up publicly available National **Action Plans (NAPs) for greening their public procurement**.

The criteria used by Member States should be harmonized to **avoid a distortion of the single market and a reduction of EU-wide competition**. Having common criteria reduces considerably the administrative burden for economic operators and for public administrations implementing GPP. Common GPP criteria are of a particular benefit to companies operating in more than one Member State as well as SMEs (whose capacity to master differing procurement procedures is limited).

The basic concept of GPP relies on having clear, verifiable, justifiable, and ambitious environmental criteria for products, based on a life-cycle approach and scientific evidence base. A wish in this sense has been expressed by the industrial sector represented by ERF.[9]

Sustainability of construction products is addressed by the CPR with the 7th **essential requirement as "Sustainable use of natural resources"**. Nevertheless, only for a few construction products a specific standard for the evaluation of environmental sustainability is being developed and the declaration of this characteristic remains at voluntary level in the CE marking scheme.

As said in the previous chapter **CPR is currently under revision** and sustainability performance require at least the same effort the manufacturers must provide for other essential requirements (i.e., structural, safety, acoustic behaviour).

To measure the sustainability performance in a fair way a specific technical standard will be required and proper criteria for a third-party certification will be needed.

For **noise barriers a draft proposal of prEN 17383[10] standard has been developed**. This document presents the Key Performance Indicators (KPIs) the noise barrier manufacturers will provide to express the performance over all the phases of the entire life cycle of the product. It will help manufacturers to better understanding on how their product can be considered "sustainable".

The declared KPIs will be referred to the manufacturing process included raw materials used and will consist of measurable quantities to **assess product sustainability**. Additional information will be provided by the manufacturer about all processes that are needed to transport, install, maintain, repair, remove and recycle the noise barriers.

This document is also intended to help manufacturers to identify the materials and product stages with the most important impact on different sustainability aspects.

Besides **manufacturers**, other users of present standard are foreseen:

(i) **designers** when calculating the Life Cycle Analysis (LCA) of the product used.

(ii) Third parties implementing infrastructure rating systems to determine how the project of the construction work has incorporated sustainability.

(iii) **Procuring entities** can use the KPIs to promote in tender specifications more sustainable solutions and innovations.

[9] Promoting Sustainable Roads Through Public Procurement – ERF document – www.erf.be

[10] prEN 17383 Road traffic noise reducing devices —Sustainability: Key Performance Indicators (KPIs) Declaration.

(iv) **Private developers** to use noise barriers on their own land like those used on public roads.

Declared KPIs will coincide with those indicated in EN 15804:2019[11]. It is than foreseen that the declaration will be released by the manufacturer according to the scheme of the **Environmental Performance Declaration (EPD)** in the framework of the DoP[12] accompanying the product when placed in the market.

2.2.2 Research projects dealing with sustainability of noise barriers

The first approach to the sustainability evaluation of noise barriers can be found within the outcomes of the **research project QUIESST**[13]. The literature review and primary research results of this research activity concluded overall that sustainability factors were not being fully considered previously. The scope of work within QUIESST project was of the holistic type and was extended to the **whole life cycle cost, calculating the carbon footprint, or designing solutions to prevent the effects of climate change**. Also, consideration was given to **social** aspects: i.e., affected community views were considered together with their engagement into the decision-making process for the choice of the noise barrier to be installed.

Furthermore, it was concluded that there was no readily available bespoke sustainability assessment tool for noise barriers. Thus, the scope of QUIESST research was that of covering the need to develop a sound methodology to assess the sustainability of noise barriers bay considering all aspects of sustainability, namely the: **technical, social, environmental, and economic factors** of sustainability for different noise barrier types.

The following scheme represents QUIESST approach to the sustainability assessment of noise barriers (see Figure 3).

The approach of the EU project QUIESST ended into the identification of more than 100 Key Performance Indicators for the four criteria at primary, secondary and in some cases, tertiary levels (see Figure 4).

Nonetheless, it was finally concluded that without a clear **multi-criteria decision-making system (MCDM)** for comparing all criteria in relationship to each other, and setting reference points, benchmarks, and optimum points for indicators (via modelling them), it would be very difficult to equitably assess the sustainability of noise barriers and rank/score them from the point of view of their sustainability.

The approach followed by QUIESST revealed to be **applicable only within design activities of complex noise barrier projects** as it requires different type of specialists not always available when a noise barrier of limited extension need to be installed.

[11] EN 15804 2012+A2 :2019, *Sustainability of construction works — Environmental product declarations — Core rules for the product category of construction products.*

[12] DoP: Declaration of Performance.

[13] QUIESST QUIetening the Environment for a Sustainable Surface Transport – Research project funded within the Seventh Framework Programme.

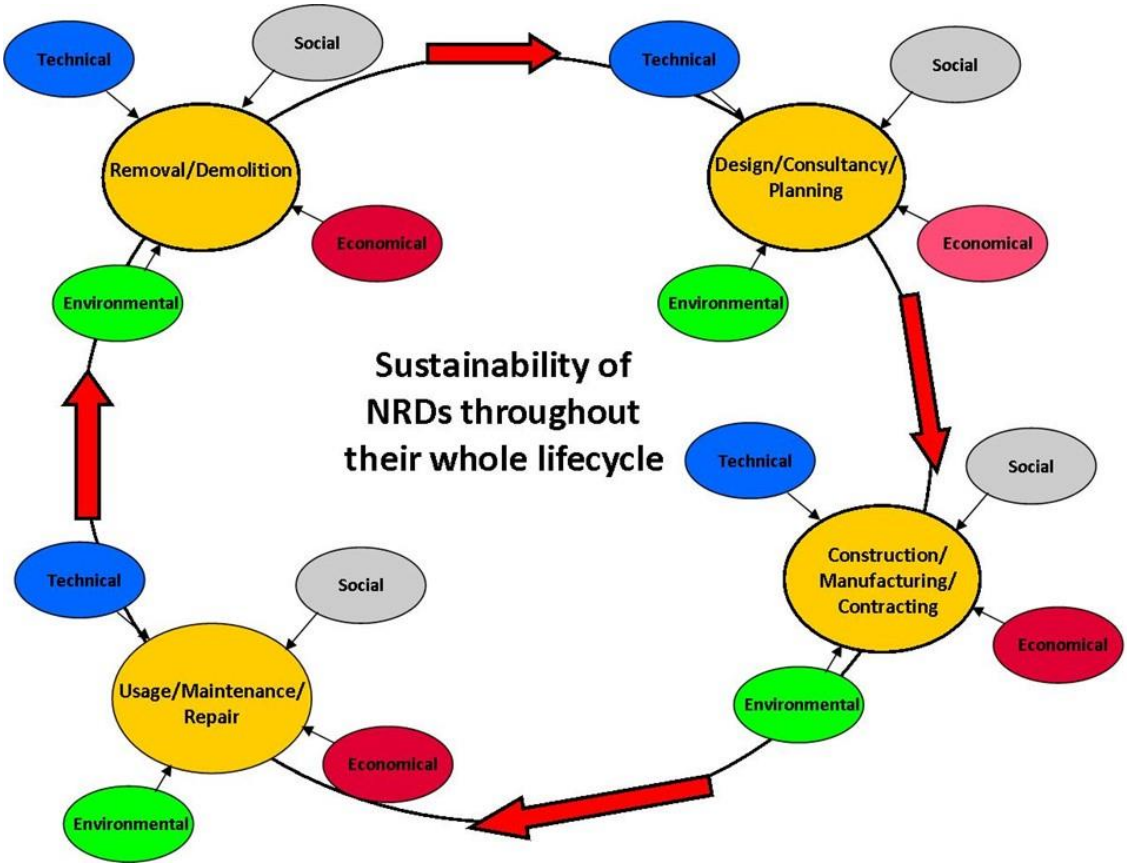


Figure 3: QUIESST approach to the sustainability assessment of noise barriers.

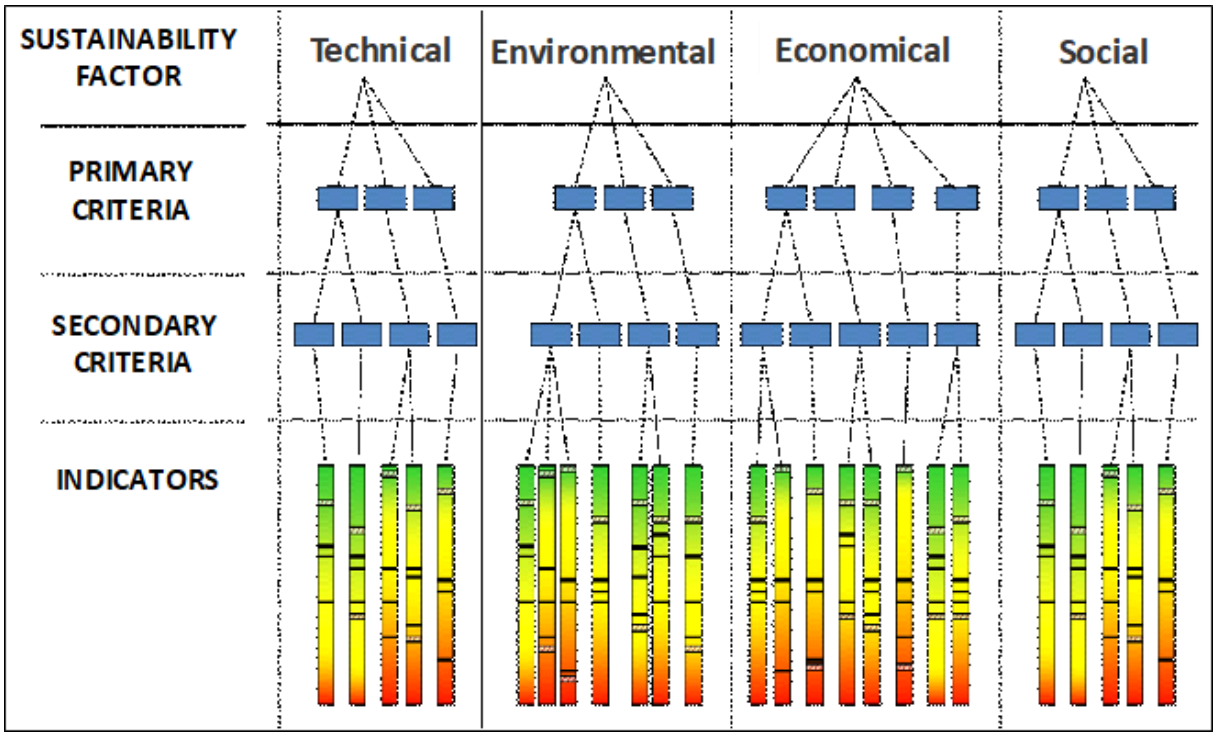


Figure 4: Top-Down and bottom-up approach to define the framework to identify criteria and indicators for noise barriers used in the project QUIESST.

Moreover, for many applications, technical requirements cannot be a part of the selection process of the optimal choice through an MCDM analysis. More likely a minimum value of structural, safety and acoustic performances need to be reached by all noise barrier solutions.

This is the consideration behind the choice made in the PROCEEDR project to prefer another, more simplified, approach as given in the following scheme presented in Figure 5, which can be named “Greek temple” approach in the frame of the present research.

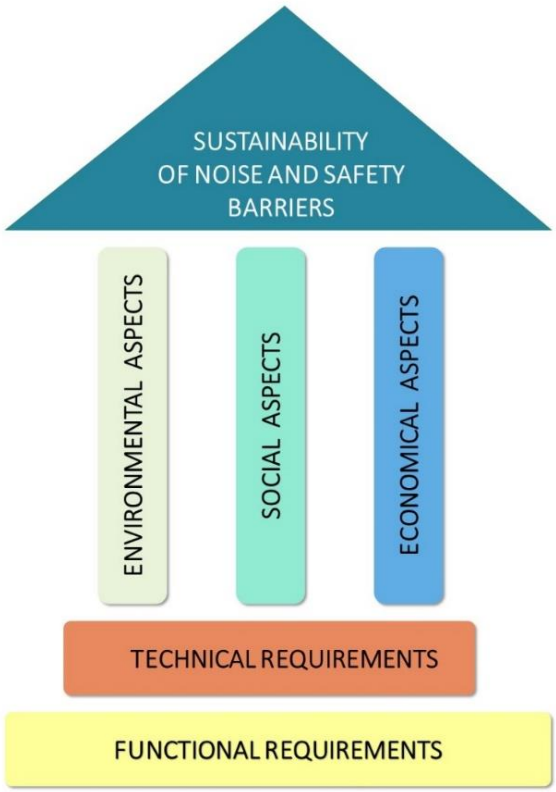


Figure 5: Greek temple approach for noise barrier sustainability assessment.

The “Greek temple” shows that for a noise barrier project **technical (and functional) requirements represents the basement**: design technical specification to be fulfilled, on the top of that for each project **economic, social, and environmental requirements** need then to be considered.

More often for a noise barrier projects economic aspects represents an additional constraint given by the limited budget available for National Road Authorities.

The **optimal choice is finally based on the evaluation of social and environmental aspects**, social aspects being those related to quality of the life of residentials besides noise protection to be achieved. Therefore, noise barriers may cause shadow of the daily light, heat highland effect, unsafe hidden areas. They may also have additional positive effects among the social ones: protection from air pollution, increase of safety for pedestrians, etc.

Regarding environmental aspects, as said, the contribution of manufacturers, providing reliable data due to the so-called **EPD approach**, is essential for the optimal choice to be made and will be the core of the software tools developed within present research.

Given the **high variability of products and materials** used for noise barriers some research activities have been carried on evaluating environmental sustainability considering different indicators calculated for the whole life cycle.

In The Netherlands relevant actions have been taken for the s**ustainability assessment of noise barriers**[14] and a recent publication (Garai et. al) [15] provides relevant results that are far from indicating the optimal solution. Instead, they show how **different indicators show different results depending on the materials considered**. Figure 6 exemplary shows how acoustic panels made of impregnated timber and transparent acryl sheets result with opposite scores for “carbon footprint” and “ozone layer depletion” indicators.

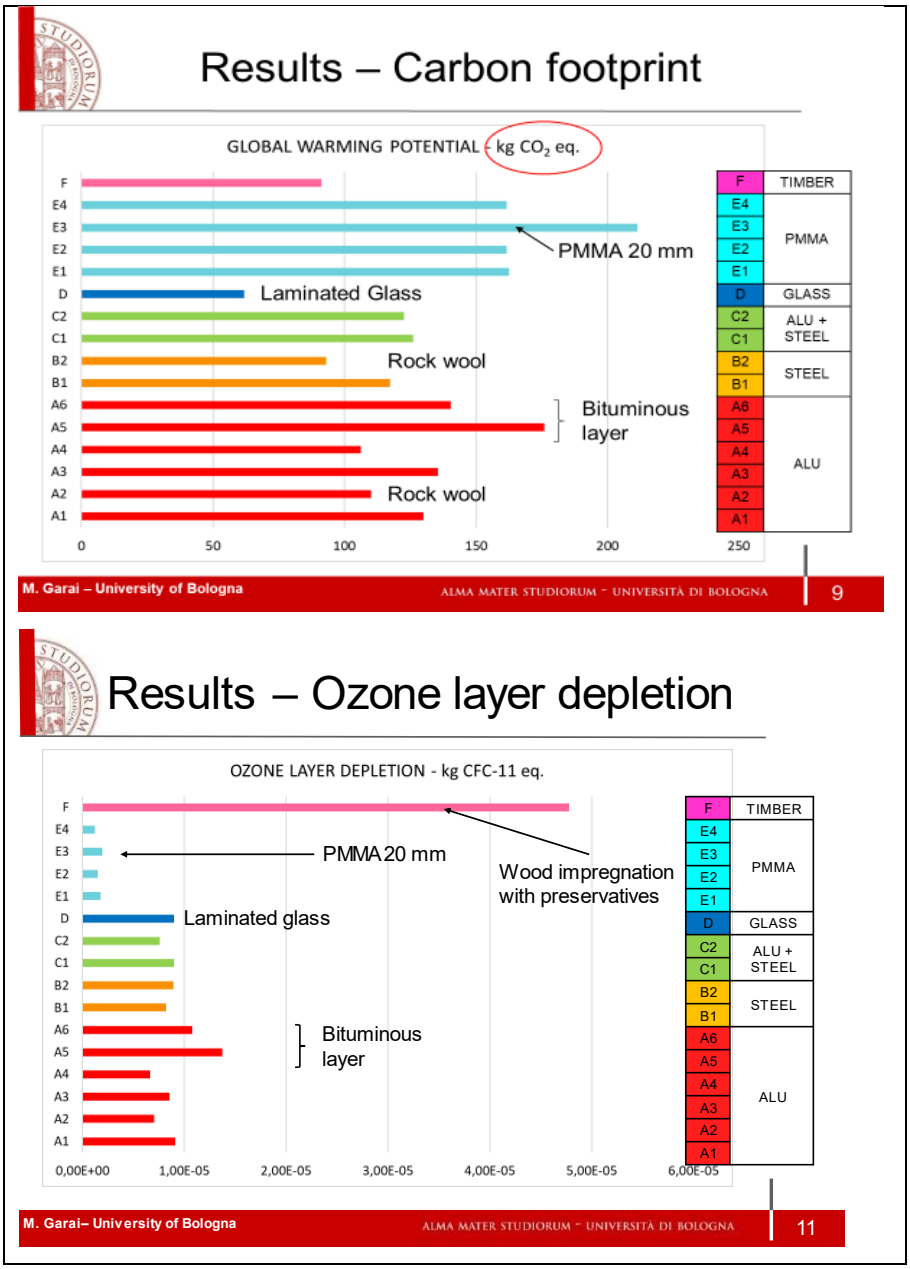


Figure 6: Exemplary results showing how timber and transparent acryl sheets reach opposite scores for carbon footprint and ozone layer depletion.

[14] https://www.rijkswaterstaat.nl/nieuws/archief/2021/01/rijkswaterstaat-legt-basis-europese-standaard-voor-duurzame-geluidschermen)

[15] Noise barriers: Environmental sustainability assessment _ Garai, Morandi, Brero _ Euronoise 2018 Crethe.

Materials play an important role in overall sustainability, nevertheless the construction of noise barrier requires relevant civil works for ground foundations or kerb reinforcement when installed on bridges or containing walls. The **evaluation of environmental aspects of foundation works** necessarily complete the information's provided by the manufacturer. They can be carried on by the designer or by the contractor itself when proposing alternative solutions.

The **prolongation of the working life** is another way to enhance the road equipment's sustainability. In this sense relevant sources of information's for present work are represented by the outcomes of **SOPRANOISE project**[16] addressing new tools to assess acoustic performances of noise barriers not only after their installation, but also throughout their whole lifetime. Noise barriers can provide very high and effective noise reduction but only if they are correctly designed, built, monitored, and **maintained during their whole lifetime**.

According to the project plan the SOPRANOISE established an engineering progressive approach with 3 successive steps, in situ visual inspections, quick measurements and full tests according to the standards EN 1793-5 and EN 1793-6. The general idea is to **assess the intrinsic acoustic performances of installed noise barriers** from the easiest (but less accurate) way up to the most accurate one (but obviously related to more effort and costs).

Both new developed steps, the in-situ inspections tool (Step 1) and the quick (acoustic) measurement method (Step 2) are a big improvement to help a methodological assessment of noise barriers sustainability, when considering the construction, the use, and the end-of-life stages. After the installation of newly built noise barriers the whole SOPRANOISE approach can be used to **verify tender requirements and legal approval**.

The SOPRANOISE approach can be used to **monitor the acoustic performance of the noise barriers on a regular basis** during the whole working life of the product and becomes a useful tool to plan maintenance activities in a more effective and efficient way (based on objectives data and results). A regular monitoring will help to better address the product choice in the **tendering process** and acquisition of new information to be used for new installation or for upgrading existing ones. Taking care for maintenance also means minimizing the impact on traffic flow. In fact, environmental consequences of traffic disruption can reach high values for some indicators thus changing the overall score of noise barrier sustainability in many situations, and this seems to be one of the most relevant impacts in the case Road Equipment.

Before taking any decision on the final displacement of a noise barrier, the SOPRANOISE approach can be also used to identify which noise barrier fields has to be discarded or not.

The innovative quick and safe methods to easily characterize installed noise in-situ, will be submitted to CEN for standardization. The scope of application for the SORPANOISE 3-step approach is summarized in Figure 7.

The output of the SOPRANOISE project should be evaluated in this context, moreover all possible benefits should be considered, having in mind how the new developed tools can help the sustainability assessment of noise barriers.

[16] SOPRANOISE Securing and Optimizing the Performance of Road trAffic Noise Barriers with New methOds and In-Situ Evaluation - CEDR project.

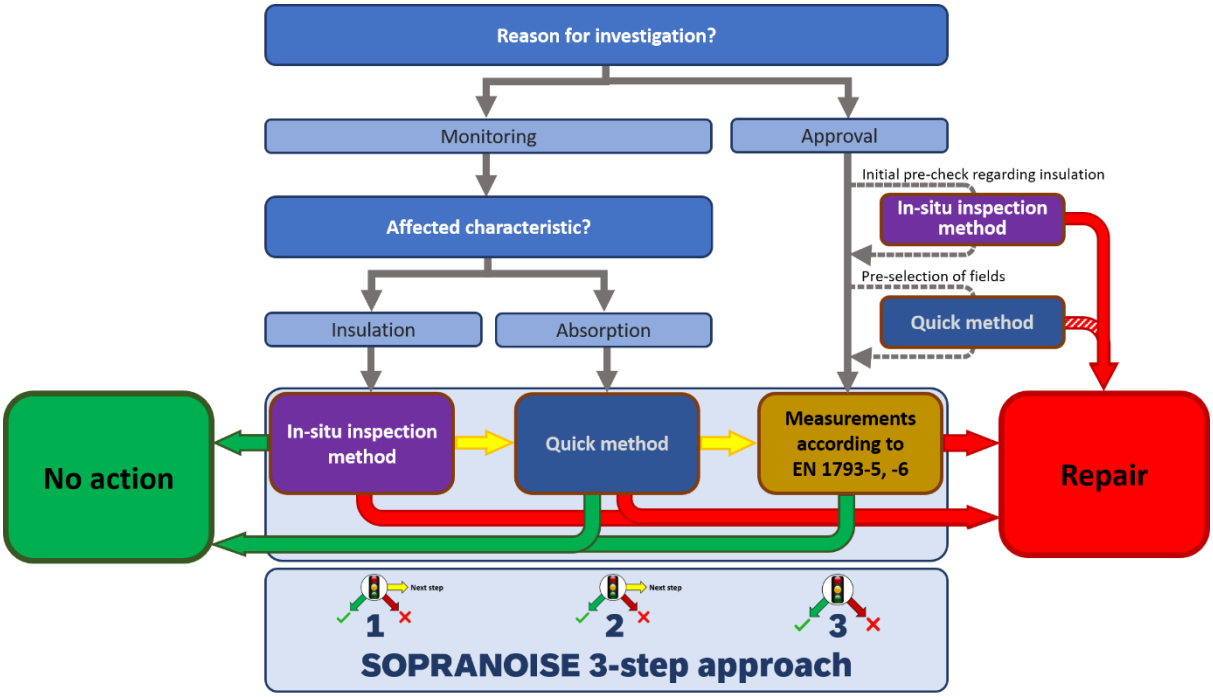


Figure 7: Flow chart visualizing the scope of the SOPRANOISE 3-step approach (see report D5.2 and D3.1 of SOPRANOISE).

Both new developed steps, the **in-situ inspections tool** (Step 1) and the **quick (acoustic) measurement method** (Step 2) are a big improvement to help a **methodological assessment of noise barrier sustainability**, when considering the following stages:

(i) The Construction installation stage A5

(ii) The Use Stages B1 to B5

(iii) And the End-of-life stage C1.

Reference is made to the following scheme taken from the standard EN 15804:2019.

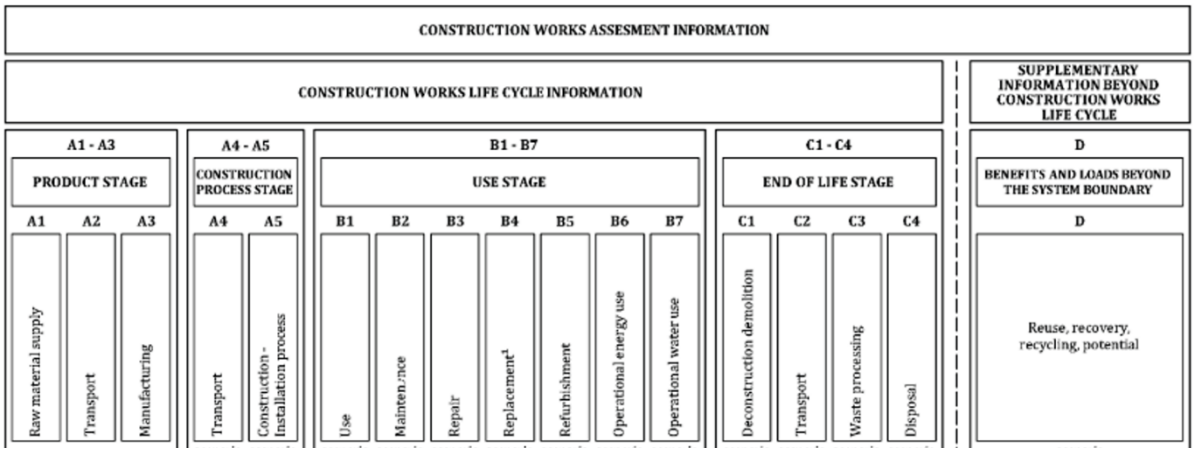


Figure 8: Scheme for sustainability assessment of construction work according to EN 15804:2019.

Compared with other construction products, for noise barrier as for other relevant road equipment (i.e., safety barriers, vertical signages, etc.) or road surfaces, a deeper attention must be paid to the **Use Stage** (B1 to B5), covering the entire working life of then product.

Taking care for maintenance also means minimizing the **impact on traffic flow**. In fact, environmental consequences of **traffic disruption** can reach high values for some indicators thus changing the overall score of noise barrier sustainability in many situations, and this seems to be one of the most relevant impacts in the case of road equipment.

The developed SOPRANOISE tools: both, the in-situ inspection and the quick measurement method can be applied in an extensive way on a large part of the noise barrier asset. If combined with the correct sampling criteria these tools will help NRAs and Road Managers to collect robust data and have updated information's about the functionality of the noise barriers installed alongside their road networks. This allows Road Managers and Operators:

(i) To **verify tender requirements** for noise barriers after installation and legal approval,

(ii) To **monitor the acoustic performance** of the noise barriers on a regular basis during the whole working life of the product,

(iii) To **plan maintenance activities** in a more effective and efficient way (based on objectives data and results),

(iv) To ideally **prolong the product working life** (considering a best-case scenario) and if not possible, the regular monitoring will help to

(v) better address the product choice in **the tendering process** and acquisition of new information to be used for new installation or for upgrading existing ones.

The following table 1 (presented in report D5.2 of SOPRANOISE) show in more detail how the SOPRANOISE methods can be applied in the different stages, following the scheme of the standard EN 15804:2019.

Table 1: How the SOPRANOISE methods can be applied in the frame of a sustainability assessment.

Construction Stages according to standard EN 15804:2019	**How the SOPRANOISE methods can be applied in the frame of a sustainability assessment**
CONSTRUCTION INSTALLATION STAGE A5	After the installation of newly built NB, the whole SOPRANOISE approach can be applied: from the in-situ inspection (step 1) to the application of the full EN methods (step 3). The SOPRANOISE approach can be used to verify tender requirements and legal approval.
USE STAGES B1 to B5 B1: Use B2: Maintenance B3: Repair B4: Replacement B5: Refurbishment	The SOPRANOISE approach can be used to monitor the acoustic performance of the noise barriers on a regular basis during the whole working life of the product and becomes a useful tool to plan maintenance activities in a more effective and efficient way (based on objectives data and results).

	A regular monitoring will help to better address the product choice in the tendering process and acquisition of new information to be used for new installation or for upgrading existing ones. Decisions about a repairment, replacement or refurbishment of the noise barrier can be based on the SOPRANOISE approach. Step 1 and step 2 can be used to identify which NB fields has to be replaced or not.
END-OF-LIFE STAGE C1	Before taking any decision on the final displacement of a noise barrier, the SOPRANOISE approach can be also used in order to identify which noise barrier fields has to be discarded or not. In particular step 1 and step 2 can be used to identify which NB fields has to be discarded.

2.2.3 Sustainability approach in the field of safety barriers

With reference to sustainability the approach for safety barriers may be represented by the same scheme of the "Greek temple" shown before, but in this case by removing the "social aspects" column, so that "*having two columns left the construction stability is still guaranteed"* (see Figure 9).

The approach for maintenance of the safety barriers is radically different concerning the noise barriers. Substitution of the product is recommended in case of accidents, loose of performance due to corrosion (in the ground or external environment) or even problems occurred to the support represented by the ground or the connection to the concrete kerb. **Safety need so be guaranteed for the entire life cycle**.

The main reason for that is the following: safety barriers are perceived as an essential part of the road construction as **they address strict safety requirements**.

Furthermore, residents are not always involved in the product selection process. An exception may be represented by **wooden barriers that are often preferred to accomplish landscape protection** requests raised by local authorities. Nevertheless, it must be remarked that wooden safety barrier represents a low percentage of the total amount of safety barrier installed alongside roads in Europe and when higher performance is required the safety behaviour in case of impact for a wooden barrier is guaranteed by its **steel reinforcement components**.

Because of the extension of their application, the safety barriers may involve **relevant investments** by Road Authorities. Costs of safety barriers are not only depending on the type of material used (steel or reinforced concrete), but also varying according to market indicators.

Transport cost, installation and maintenance activities and related traffic disruption are to be considered. Care needs also to be taken for the **foundation works** (terrain or bridge kerb reinforcement) and the adaptation of the road surface for the new barrier to be installed (water removal from the road platform).

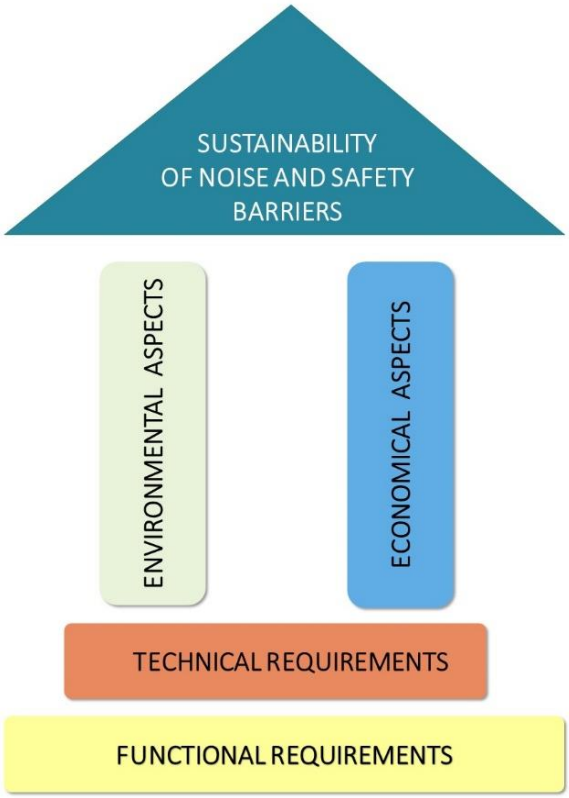


Figure 9: Greek temple approach for safety barrier sustainability assessment.

Considering environmental requirements in the sector of safety barriers a complementary Product Category Rules cPCR[17], developed in the **framework of the International EPD System**, document has been published. This document constitutes: a program for type III environmental declarations according to ISO 14025:2006.

Environmental Product Declarations (EPD) are voluntary documents for a company or organization to present transparent information about the life cycle environmental impact for their goods or services.

cPCR about Guardrails and bridge parapets cannot be used by itself but shall be used together with PCR 2019:14 Construction Products and the European standard EN 15804:2012+A2:2019. This document has been developed with the support of both steel and precast concrete safety barriers.

Barriers of different height above the road surface show different performances in term of containment levels of errant vehicles, thus the choice of considering the linear dimension unit to calculate sustainability indicators allows for the comparability of different products.

When considering the general system boundaries, it appears that **all life cycle phases have been considered except for the "use stage"**. Compared with other construction products (i.e., building components that may affect the energy behaviour of the building) road equipment's remain passive along the life cycle. Nevertheless, these equipment's imply different levels of maintenance activities that could affect the total score of sustainability indicators.

[17] complementary Product Category Rules (c-PCR) to PCR 2019:14 date 2021-04-23 – about guard-rails and bridge parapets.

Another secondary impact that should be considered is the **traffic disruption** of road equipment's is the following phases of Life Cycles, Installation, maintenance (when considered) and the deconstruction phase. Traffic disruption depends on the traffic intensity of different types of roads. **It is then a site dependent indicator,** nevertheless information's should be given to allow further calculation of this secondary impact. At least information should be related to installation and deconstruction rate, foundation works, type of equipment's required, frequency and type of maintenance activities both for ageing of the product and for repairing after accidents.

With reference to cPCR about Guardrails and Bridge Parapets a few EPD have been registered by manufacturers and published on the website www.environdec.eu. Results provided in these documents will be considered in the next steps of the present research project.

The German association of manufacturers has published a document showing a LCA study for **steel safety barriers**[18]. From this study it results how the impacts from raw materials dominate the overall sustainability score of the final products. In facts following directions for improvement can be envisaged:

(i) use of new materials. At present steel and concrete remains the only material idoneous to ensure the fulfilment of essential structural requirements.

(ii) To identify new surface treatments of steel components

(iii) Avoid supply of materials from long distance.

Steel protection to the corrosion by mean of galvanization process seems a major issue because of the zinc release into the ground. Different approaches have been taken:

(i) Reduction of zinc protection layer by using pre-galvanisation techniques.

(ii) Use of biobased materials [19], [20]

Regarding **timber safety barriers** an EPD has been found as registered[21].

In the next chapter a **classification of most common noise barrier and safety barrier** types in Europe will be drafted, giving an overview of the whole life cycle.

[18] Umwelt Produktdeklaration STUDIENGESELLSCHAFT FÜR STAHLSCHUTZPLANKEN e.V. – Stahlschutzplanken, EPD-SSS-20150286-IBE1-DE

[19] https://www.biobasedeconomy.nl/2015/05/15/testen-biobased-geleiderail-op-grevelingendam

[20] https://bg4us.eu/

[21] https://www.houtindegww.nl/wp-content/uploads/2020/04/houten-geleiderail-a-weg-rev1-201906211051-short.pdf

3 Overview of noise and safety barrier used in Europe

The main scope of this chapter is to draft a tentative classification of the noise and safety barriers mostly used in Europe and to give a general overview of the following life cycle stages:

(i) raw material used and relevant **material treatments**

(ii) production / **manufacturing** process

(iii) **transportation** to the construction site

(iv) installation / **construction** stage

(v) **maintenance** stage

(vi) **end of life** stage.

3.1 Tentative classification of the most common noise and safety barrier types in Europe

Noise barriers covers a high variety of materials and construction processes. The diversity of solutions used is due to **the different approach in various countries based on different cultural background, design approach and industrial background**.

In some countries in **central and southern Europe (e.g., in Germany, Austria, The Netherlands, Belgium Switzerland and Italy)** noise barriers are based on standard schemes composed of structural elements /made of steel beams or concrete pillars) and acoustic elements (typically metal or timber cassettes or concrete panels). A large use of transparent elements helps to minimize the visual impact of solid walls. Other products have been introduced on the market (i.e., PVC cassettes). This industrial approach prevailed also in other southern countries like Spain and Greece or in **Eastern EU countries** when the use of noise barrier emerged during the last 10 years.

An architectural approach is more evident in **France** where noise barriers is a country where noise barriers are usually planned by architects.

In **Northern EU countries like UK, Sweden, Denmark, and Norway** green walls or earth berms are often preferred.

A suggestion for classification is presented in Table 2. It is a try to cluster the most common types of noise and safety barriers currently used in Europe in meaningful classes, therefore this should be considered as a starting point for following discussions in PROCEEDR. This classification cannot be assumed as a rigid scheme. it should be mentioned that the presented classification for noise barriers have been already used in other research projects like QUIESST and SOPRANOISE.

In the field of safety barriers, a more standard approach, mainly due the need of fulfilling functional characteristics, is requested: the main materials used in this case are steel, concrete and timber. Furthermore, there is also some special devices as crash cushions, which may be made of different materials.

Special attention should be also given to some peculiar products where both functions are integrated and placed on the market as a unique system for being used as **noise and safety barrier at the same time.** 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.

Table 2: General classification of noise barrier types and safety barrier types currently used in Europe according to the EU project QUIESST and to the authors of this report.

Noise barrier types (including road coverings and earth berms)		
	SC	Steel support structure + Concrete panels
	SW	Steel supporting structure + Wooden panels
	SM	Steel supporting structure + Metal panels
	ST	Steel supporting structure + Transparent modules
	SP	Steel supporting structure with plastic panels
	CB	Self-supporting concrete or brick system
	GB	Green barrier
	EB	Earth barrier (earth berm)
	RC	Road covering structure (including artificial tunnels)
Safety barrier types		
	SB	Steel safety barrier
	WB	Mixed wood steel safety barrier
	PB	Precast concrete safety barrier
	IC	In situ cast concrete safety barrier
	CC	Crash cushion
	IB	Integrated noise safety barrier

The tables presented in the next sections provides a short description and a breakdown of different stages for the life cycle. Subjects involved are:

- The **manufacturer of the road equipment** (noise or safety barriers) transforming the raw material into the final product placed on the market. To be considered that some activities may be subcontracted or in some cases raw materials may be pre-processed by the **supplier**.
- **Installer or Contractor** is the company in charge of the installation works. This company may have the role of Contractor or may be a subcontractor of the manufacturer depending on the size of the contract, the type of product and the procurement regulations in different countries
- **Road Authority** (e.g., NRAs) or the road manager having the role of maintaining the road equipment during the working life until final dismantling

3.2 Description of the life cycle stages for the most common noise barriers in Europe

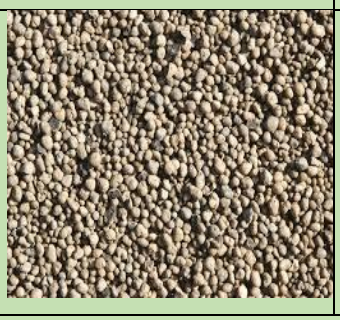
The following tables describes the stages of the whole life cycle of the most relevant noise barrier types used in Europe. After a short description of the noise barrier types, the raw material used, and the manufacturing and production process are briefly shown. After that the transport to the installation site, the installation itself, the monitoring and the end-of-life phases are finally described including also relevant pictures of the most relevant processes.

Foundation works are not included in the following tables as they are part of the civil works. Nevertheless, specific analysis can be performed, especially where foundation system and structural elements are integrated.

3.2.1 Life cycle stages for noise barriers made of steel supporting structure and concrete panels

Table 3: Life cycle stages for noise barriers made of steel supporting structure and concrete panels.

SC	**Steel supporting structure + Concrete panels**
	
Description: noise barrier made of structural elements (steel posts + base plate and anchor bolts) + acoustic elements made of a double layer concrete panel (supporting layer made of steel reinforced concrete + sound absorbing layer made of light concrete, expanded clay, mixed concrete and wooden chips).	
Raw materials used	
Hot rolled steel profile of the open type Different steel grades Supplied in bars.	

Steel plates Different steel grades.		
Steel bars for structural concrete reinforcing.		
High grade cement and concrete aggregates.		
Light concrete / expanded clay / wooden mineralized chips.		
Manufacturing process		
Cutting – Bending - Welding of steel profiles for supporting structure.		

Galvanization process of supporting steel structure.	
Casting of the concrete panels in moulders Or casting of the concrete sound absorbing tiles.	 
Transport to the installation site Truck 40 tons Weight is determining the maximum use of the transport.	
Installation Equipment' s: truck with a crane Teams of 5 workers + site manager Traffic disruption: emergency lane + first lane.	

Maintenance Supporting structure working life: 25 years Acoustic elements working life: 20 years Maintenance activities may be required for the effect of accidents / vandalism Or deterioration of light concrete surface
End of life Recycling procedure for concrete manufatcs.

3.2.2 Life cycle stages for noise barriers made of steel supporting structure and timber panels

Table 4: Life cycle stages for noise barriers made of steel supporting structure and concrete panels.

SW	**Steel supporting structure + Timber panels**
	
Description: noise barrier made of structural elements (steel posts + base plate and anchor bolts) + acoustic elements made of timber cassette with an inner sound absorbing material (rockwool, glass wool or polyester foam.)	
Raw materials used	
Hot rolled steel profile of the open type Different steel grades Supplied in bars.	

Steel plates Different steel grades.	
Wooden structural beams and wooden beads of pine, fir, larch essence.	 
Inner materials mineral wool or polyester foam.	 
Bolts and self-perforating screws rivets.	
Manufacturing process	
Cutting – Bending - Welding of steel profiles to achieve.	

Galvanization process of supporting steel structure.		
Cutting to size of wooden components		
Timber impregnation and painting		
Manual assembling of the components		
Transport to the installation site Truck 40 tons or 20-40 feet container Weight is determining the maximum use of the transport.		
Installation Equipment' s: truck with a crane Teams of 5 workers + site manager Traffic disruption: emergency lane + first lane.		
Maintenance Supporting structure working life: 25 years. Acoustic elements working life: 15 years. Maintenance activities may be required for the effect of accidents / vandalism. Detachment of wooden components because of the failure of the screw or junction made through knots in the wood.		

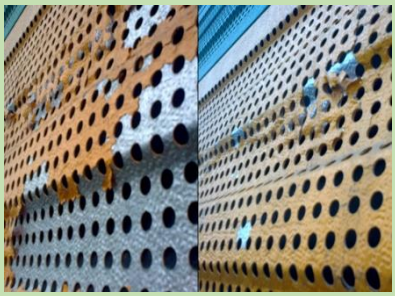
End of life
Mineral wool: the policy of main suppliers is that of recycling mineral wools to meet a target to take back a certain percentage of the scrap generated from their customers' job sites. Recycling policy of impregnated timber is to be considered as potential issue.

3.2.3 Life cycle stages for noise barriers made of steel supporting structure and metal panels

Table 5: Life cycle stages for noise barriers made of steel supporting structure and concrete panels.

SM	**Steel supporting structure + Metal panels**
	
Description: noise barrier made of structural elements (steel posts + base plate and anchor bolts) + acoustic elements made of a metallic cassette (steel or aluminium) with an inner sound absorbing material (rockwool, glass wool or polyester foam).	
Raw materials used	
Hot rolled steel profile of the open type Different steel grades. Supplied in bars.	

Steel plates Different steel grades.	
cold rolled steel coils or aluminium coils.	
Inner materials mineral wool or polyester foam.	 
Bolts and self-perforating screws rivets	
Manufacturing process	
Cutting – Bending - Welding of steel profiles to achieve.	
Galvanization process of supporting steel structure.	

mechanical roll forming line to shape the metallic cassette out of the aluminium or steel coil.		
Powder or liquid coating line.		
Transport to the installation site		
Truck 40 tons or 20-40 feet container Weight is determining the maximum use of the transport.		
Installation Equipment' s: truck with a crane Teams of 5 workers + site manager Traffic disruption: emergency lane + first lane.		
Maintenance Supporting structure working life: 25 years Acoustic elements working life: 15 years Maintenance activities may be required for the effect of accidents / vandalism Or deterioration of the steel coating due to environmental agents.		

End of life both steel and aluminium components may be recycled mineral wool: the policy of main suppliers is that of recycling mineral wools to meet a target to take back a certain percentage of the scrap generated from their customers' job sites.	

3.2.4 Life cycle stages for noise barriers made of steel supporting structure and transparent modules

Table 6: Life cycle stages for noise barriers made of steel supporting structure and transparent modules.

ST	**Steel supporting structure + Transparent modules**
	
Description: noise barrier made of structural elements (steel posts + base plate and anchor bolts) + acoustic elements made of transparent modules (transparent sheets made of solid polymethylmethacrylate, polycarbonate or laminated glass equipped with a metallic frame).	
Raw materials used	
For supporting structure: Hot rolled steel profile of the open type Different steel grades Supplied in bars.	

For supporting structure: Steel plates Different steel grades.	
For PMMA /PC sheets: MMA or polycarbonate granules used for further polymerization process.	
For laminated glass sheets: Float glass made of sand, soda ash and limestone.	
For transparent sheets of all types: Steel profiles + EPDM gasket for the transparent sheet frame.	
Manufacturing process	
Cutting – Bending - Welding of steel profiles to achieve the required shape and dimensions.	

Galvanization process of supporting steel structure.		
Manufacturing of PMMA or PC sheet through extrusion process.		
Laminated Glass manufacturing: Tempering, PVB adhesion, lamination.		
Transport to the installation site		
Truck 40 tons or 20-40 feet container Weight is determining the maximum use of the transport for PMMA or PC sheets Volume of stacks is determining maximum use of the transport for laminated glass sheet.		

<table>
<tr><td colspan="3">Installation</td></tr>
<tr><td>Equipment’ s: truck with a crane

Teams of 5 workers + site manager

Traffic disruption: emergency lane + first lane

PMMA/PC sheets can be cut to size on site if required.</td><td colspan="2">  </td></tr>
<tr><td colspan="3">Maintenance</td></tr>
<tr><td>Supporting structure working life: 25 years

Acoustic elements working life: 15 years

Maintenance activities may be required for the effect of accidents / vandalism

Graffiti removal may be an issue for PMMA or PC sheets.

Laminated glass may be subject to breaking.</td><td>  </td><td>  </td></tr>
<tr><td colspan="3">End of life</td></tr>
<tr><td>Both PMMA/PC and laminated glass sheets may be subject to recycling process.</td><td colspan="2">  </td></tr>
</table>

3.2.5 Life cycle stages for noise barriers made of steel supporting structure with plastic panels

Table 7: Life cycle stages for noise barriers made of steel supporting structure with plastic panels.

SP	**Steel supporting structure + plastic panels**
***Description**:* noise barrier made of structural elements (steel posts + base plate and anchor bolts) + acoustic elements made of a plastic (PVC) cassette with an inner sound absorbing material (rockwool, glass wool or polyester foam).	
	
Raw materials used	
For supporting structure: Hot rolled steel profile of the open type. Different steel grades. Supplied in bars.	
For supporting structure: Steel plates. Different steel grades.	

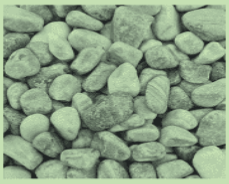
For plastic acoustic panels: Recycled PVC (i.e., from window frames).	
For plastic acoustic panels: Inner materials polyester foam.	
Bolts and self-perforating screws rivets.	
Manufacturing process	
Cutting – Bending - Welding of steel profiles to achieve the required shape and dimensions.	
Galvanization process of supporting steel structure.	

Cassette PVC extrusion and panel assembling.		
Transport to the installation site		
Truck 40 tons or 20-40 feet container. Volume is determining the maximum use of the transport.		
Installation		
Equipment' s: truck with a crane Teams of 5 workers + site manager Traffic disruption: emergency lane + first lane.		
Maintenance		
Supporting structure working life: 25 years Acoustic elements working life: 15/20 years Maintenance activities may be required for the effect of accidents / vandalism.		

End of life	
PVC can be fully re-granulated for another lifecycle.	

3.2.6 Life cycle stages for noise barriers made of self-supporting concrete or brick system

Table 8: Life cycle stages for noise barriers made of of self-supporting concrete or brick system.

SC	**self-supporting concrete or brick/stone system**		
			
Description: noise barrier made of self-supporting concrete elements (either prefabricated or cast in situ) or brick/stone system as construction.			
Raw materials used			
Reinforced concrete. Bricks. Steel gabions with stones.			
Manufacturing process			
For raw material / components or prefabricated elements panels only.			

Transport to the site	
for raw materials and prefabricated elements only. Weight is determining the maximum use of the transport.	
Installation / Construction	
Manpower and equipment's required is project and site dependant.	
Maintenance	
Current maintenance activities for construction works required.	
End of life	
Deconstruction and recycling as per other construction works.	

3.2.7 Life cycle stages for green noise barriers

Table 9: Life cycle stages for green noise barriers.

<table>
<tr><td colspan="2">GB green noise barriers</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td colspan="2">Description: green noise barriers are made of a supporting structure (based either on steel or concrete elements) holding terrain and vegetation.</td></tr>
<tr><td colspan="2">Raw materials used</td></tr>
<tr><td>Concrete or steel supporting structure.
Earth.
Vegetation of different types.</td><td>  </td></tr>
<tr><td>Manufacturing process</td><td></td></tr>
<tr><td>Current casting procedure for concrete elements.
Current cutting and welding procedures for steel components.</td><td> 
  </td></tr>
<tr><td>Transport to the site</td><td></td></tr>
<tr><td>for the supporting structure only
concrete structure raw materials and prefabricated elements only.</td><td>  </td></tr>
</table>

Installation / Construction		
Manpower and equipment's required is project and site dependant.		
Maintenance		
Major maintenance activity required. For earth and vegetation replacing may be required.		
End of life		
Deconstruction and recycling as er other construction works.		

3.2.8 Life cycle stages for earth noise barriers (earth berms)

Table 10: Life cycle stages for earth noise barriers (earth berms).

EB **Earth berms**	
	
Description: earth berms for noise protection are embankments covered by vegetation.	

Construction	
Earth movement activity project and site dependant. Vegetation planting.	
Maintenance	
Major maintenance activity required. For vegetation replacing.	
End of life	
Made by earth movements activities.	

3.2.9 Life cycle stages for road noise coverings

Table 11: Life cycle stages for road noise coverings.

RC Road noise coverings	
	
Description: Road coverings are artificial tunnel able to provide a total noise screening. They can be made of a combination of the products and solutions listed above. They must be considered construction works.	

3.3 Description of the life cycle stages for safety barriers

The following tables describes the stages of the whole life cycle of the most relevant safety barrier types used in Europe. After a short description of the noise barrier types, the raw material used, and the manufacturing and production process are briefly shown. After that the transport to the installation site, the installation itself, the monitoring and the end-of-life phases are finally described including also relevant pictures of the most relevant processes.

3.3.1 Life cycle stages for noise barriers made of steel safety barriers

Table 12: Life cycle stages for noise barriers made of steel safety barriers.

SB - Steel safety barriers	
	
Description: Safety barrier made of steel. Semi-rigid barriers, usually made from steel beams or rails. Most common type is the W-Beam steel barrier.	
Raw materials treatments	Different grades of hot rolled, perforated, hot-dip galvanised steel; steel posts; bolt, nuts, washers. The raw materials are used in coils. Killed or mild steel must be used for steel safety barriers otherwise they degrade over years and can become brittle. (Use of secondary material: % of scrap steel could be re-used for production).
Production phases	Horizontal parts are stamped and edged on a press. Vertical parts are shaped on profile machinery. Other construction parts are made on different hydraulic and ex-centre presses, welding robots or manual welding stations. Surface treatment is performed through galvanisation for surface protection – hot dip galvanising and strip galvanising.

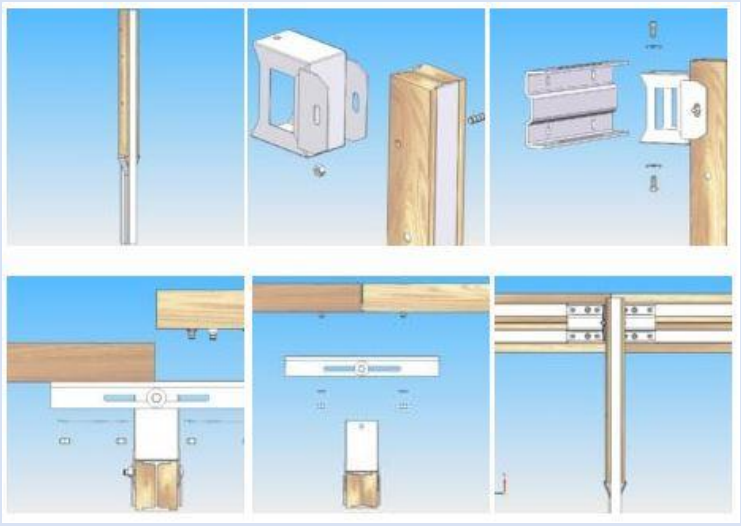
	
Transportation to the construction site	Use of 16-32 metric tonnes truck. To optimise safety barrier installation and avoid obstructions on site, only the barrier material required on the day should be delivered at site.
Installation/ construction phase	Equipment: 7.5 to 10 tonnes truck, compressor, pneumatic rammer, and pneumatic hand tools. Hydraulic equipment for drilling or ramming in heavy ground conditions. Personnel: 3-5 workers + site supervisor. Traffic disruption: emergency lane. 
Maintenance	Service lifetime: 50 years. Maintenance: cleaning, renewal of barrier anti-corrosion coatings, exchange of corroded barrier joints, inspection rounds. Repairs usually relate to barrier crashes, barrier damage.

End of life **Reuse – Recovery – Recycling potential**	At end of service life, the safety barrier parts should be de-assembled and collected separately. Some manufacturers have a EPD (Environmental Product Declaration). Steel road barriers are almost 100% recyclable. 99% of used steel is regained after dismantling (assumption of 1% going into landfill due to unforeseen loses after the removal of the steel road restraint systems).

3.3.2 Life cycle stages for mixed wood steel safety barriers

Table 13: Life cycle stages for mixed wood steel safety barriers.

WB - Mixed wood steel safety barriers
 
Description: Combined wood and steel guardrails adapted to natural sites, ensuring aesthetic continuity. These types of barriers are in accordance with EN-1317 European standards.

Raw materials treatments	Galvanised steel rail, wood logs (usually Sylvester/Scots pine). Coating: Galvanised, pre-galvanised, weathering steel. Washers, bolts, nuts, reflective elements. Guardrail components: 1. Rail formed of a wooden bar or beam, simple or composite, armed by one or various internal, external or partially metallic profiles inserted in the wooden beam. The beam can have multiple shapes and configurations: full round log, half round, section quadrangular, rectangular, polygonal or other shapes. The metal arming profile can be a silver band, flat or curved, interior or exterior, or a metal profile in "U" shape with wings inserted, totally or partially inside the wooden beam. 2. The post, formed by a metallic profile of U-shaped section, "C", sigma or section round, coated partially in its emerging part of the land by a cover of single piece wood, arranged vertically at regular intervals and fixed to the rail. 3. Sometimes, there is also a separator, consisting of plates or metallic profiles shaped in tubular, square or rectangular sections, presenting assembled wood elements.
Production phases	The wood is pressure treated with chromium and arsenic-free preservatives. The rails are built with 2 half round wood logs, sometimes backed with a steel U profile inserted in the wooden rails. Moisture content of the wood must be less than 30% before impregnation. The wood is impregnated in "vacuum and pressure" autoclave according to EN 335.
Transportation to the construction site	Transportation into either a full truck or a 20ft container.
Installation/construction phase	Horizontal rails are pre-assembled in factory (wood and metal together). Assembly is easy and little maintenance is required. 

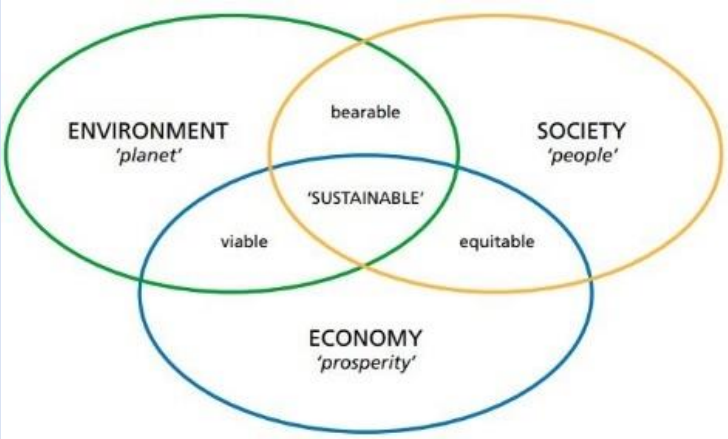
Maintenance	Service lifetime: 25 years
End of life **Reuse – Recovery – Recycling potential**	Fully recyclable, steel's superior performance minimised environmental impact when measured through the entire product life cycle. Recyclable and biodegradable, the autoclaved wood is 100 % recyclable through normal channels

3.3.3 Life cycle stages for precast concrete safety barriers

Table 14: Life cycle stages for precast concrete safety barriers.

PB - Precast concrete safety barriers	
 	
Description: Pre-cast barriers are ideal for temporary traffic situations (e.g., major maintenance), as the barriers can be taken to storage or moved to another site. They can also be used for tidal flow and temporary traffic control situations. Types: New Jersey (older), Type-F concrete safety barriers.	
Raw materials treatments	Cement, aggregates, admixtures, and steel reinforcement. Concrete is specified according to EN 13369. With the use of blended cement types or the addition of fly ash or ground granulated blast furnace slag, the embodied CO2 of the barrier can be reduced. The use of recycled concrete aggregates (RCA) is also permitted.
Production phases	Pre-cast concrete barrier elements are factory produced in reinforced concrete. The reinforcement is performed with steel strand or 100% recycled scrap using an electric arc furnace process.

	
Transportation to the construction site	The barriers are transported at the site with a truck. For large quantities, a depot in the vicinity of the site is made, from where the barriers are transported to the site.
Installation/construction phase	The installation is usually executed by the supplier, although the barriers can also be self-installed if needed (using a standard forklift truck). The contractor must ensure the right place of installation and a flat surface, usually asphalt. The barriers are manufactured in an indoor environment and assembled at the worksite; their installation is less dependent on climatic conditions. Barriers must comply with the clauses of annex ZA of EN 1317-5 so that the barrier system is installed as tested to the Type Testing (TT) and in accordance with the Manufacturer's Installation Manual. 

Maintenance	Almost maintenance free over their 50-year service life. They remain functional even after severe collisions.
End of life **Reuse – Recovery – Recycling potential**	Minimum material usage and waste. Non-polluting in service. Concrete barriers can be constructed using recycled materials, therefore are 100 % recyclable, providing secondary aggregates that can be reused in a wide range of applications. 

3.3.4 Life cycle stages for in situ cast concrete safety barriers

Table 15: Life cycle stages for in situ cast concrete safety barriers.

IC – In-situ cast concrete safety barriers
 
Description: The concrete step barrier is Europe ‘s standardised solution for in situ barriers. The concrete barrier is poured on site, situated directly on the road, with the use of slipform machine by means of a mould.

Raw materials treatments	Concrete is specified according to EN 206. It is possible to use blended cement types, or additions of fly ash, ground granulated blast furnace slag. Low-slump concrete with crushed gravel or limestone aggregates are typically used. Recycled aggregates can also be used for concrete barriers. Along the length of the barrier, two galvanised steel strands are included.
Production phases	Concrete is mixed according to EN 206 and taken at the installation site.
Transportation to the construction site	Concrete mixer and slipform paver are necessary at the construction site. 
Installation/construction phase	The in-situ installation is done by means of a custom slipform paver with a mould, using ready mixed concrete. To avoid deformation of the extruded profile, low-slump concrete with crushed aggregates should be applied, to obtain a stable mixture. This kind of installation allows very high daily production rates (400 to 600 meters) and consequently competitive prices. The barrier can be tied to the substructure (a cement treated or asphalt base layer) or can be surface mounted without any anchoring. Concrete barriers require less space than other barrier solutions (typically 0.6 – 0.8 metres), depending on containment level.

	
Maintenance	Service life of minimum 50 years. Concrete barriers require minimal levels of service life maintenance activity (low levels of road user disruption and congestion with no lane closures).
End of life **Reuse – Recovery – Recycling potential**	Concrete barriers are 100% recyclable, providing good quality secondary aggregates for a wide range of applications. Concrete does not contain any pollutants and will not present any environmental risk when used on the motorway. This also applies when crushed recycled concrete is used in other unbound applications.

3.3.5 Life cycle stages for crash cushions

Table 16: Life cycle stages for crash cushions.

CC - Crash cushions	
	
Description: Crash cushions are a road vehicle energy absorption device installed in front of rigid objects to contain and redirect a vehicle (i.e. redirective crash cushion) or to contain and capture it (i.e. non-redirective crash cushion). Crash cushions are tested in accordance with EN 1317-3.	

Raw materials treatments	Crash cushions can be manufactured from different materials, in several sizes and weights and for several speed classes. These factors influence the materials and treatments of the crash cushions. The components include energy-absorbing chambers/cartridges/modules (made of PVC, aluminium, polyethylene, or other lightweight crushable materials), a solid framework made of galvanised steel guardrails or beam panels, bolts, nuts, washers etc.
Production phases	Pre-assembled in factory and delivered fully assembled at site.
Transportation to the construction site	Truck with crane attachment, team of 2-3 workers depending on the type of crash cushion.
Installation/construction phase	Depending on manufacturers, crash cushions can sometimes require special foundations for installations. They can be installed on the concrete slab or directly into the asphalt using imbedded fixing bolts (rustproof), anchoring chains/cables or a special adhesive. Most can be connected to standard concrete barriers or steel guardrails. 
Maintenance	Crash cushions require no maintenance unless they have undergone an impact. Even then, most crash cushions require only replacement of the absorbing compartments.
End of life **Reuse – Recovery – Recycling potential**	After a standard impact, it is possible to change only the absorbing panels of the crash cushion. As such, crash cushions are simple and inexpensive to restore. Steel is 100 % recyclable. However, the plastic and other materials used for the absorbent modules are not easy to recover at site (i.e., after an impact) and are not easily recyclable.

3.3.6 Life cycle stages for integrated noise safety barriers

Table 17: Life cycle stages for integrated noise safety barriers.

IB - Integrated noise safety barriers	
 	
Description: Safety barrier that also serves the function of a noise barrier. Integrated barriers using both concrete and steel guard rails have to pass EN 1317-1 and EN 1317-2 for fulfilling safety requirements and EN 14388 for fulfilling all acoustic requirements.	
Raw materials treatments	Safety barrier can be made of hot-dip galvanised steel or concrete. Depending on the category (reflective, absorbent, mixed), noise barriers can be made of concrete, wood-concrete, steel sheets (painted, galvanised, stainless, Corten), aluminium, transparent polymethylmethacrylate panels, brick, plastic, and others (for more details on this topic see classification of noise barriers at the beginning of this chapter). Other elements include spacers, tubes, safety steel cables, screws, bolts etc.
Production phases	Pre-assembled concrete barriers and steel barriers are manufactured in factories and transported to the site. Noise barriers are also manufactured in factories.
Transportation to the construction site	Trucks for transporting the base elements and panel trailers for the nose barrier elements. The noise protection elements should be secured, to avoid toppling during transportation and installation. Loading crane /mobile cranes are used with appropriate anchorage systems. Lane closures are needed.

	
Installation/construction phase	Simultaneous installation of concrete barriers and noise barriers. Easy installation (approximately 300 meters in 8 hours). No anchorage or foundation needed in the soil.  
Maintenance	Concrete barriers have a service life of 50 years. Aluminium, steel, and wood barriers have an estimated service life of 25 years. Steel safety barriers may need to be replaced after a vehicle impact. Concrete and masonry barriers require little to no maintenance during their service life. Transparent sections of noise barriers require regular cleaning and may have to be replaced during their service life.
End of life **Reuse – Recovery – Recycling potential**	Concrete is 100% recyclable. Steel is almost 100% recyclable. Plastic acoustic elements can be manufactured from recycled plastics reinforced with glass fibre.

4 Development and analysis of the PROCEEDR survey for industry stakeholders

In this chapter the development of the PROCEEDR surveys is explained, including the specific questions asked in the surveys. After that, the statistical results of the survey for industry stakeholders are shown in more details.

4.1 Survey development

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:

- first a questionnaire with special focus on NRAs has been developed.
- 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, suppliers, producers, and contractors.

The original surveys are presented respectively in Annex A and Annex B. Both questionnaires have been circulated from November 2021 to March 2022.

4.1.1 Survey for NRAs

The results of the survey for NRAs have been analysed and explained in the PROCEEDR report D1.1" Report on existing LCA/LCCA-tools and roadside infrastructure solutions including a SWOT analysis of existing tools", where the multi-life-cycle-based tools currently available are summarized.

Nevertheless, it is relevant to show also in this reports the requested issues also for this first survey. Thus, the survey for NRAs hast directly asked to the National Road Authorities involved in the project the following questions:

- 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?

4.1.2 Survey for industry stakeholders

Regarding the questionnaire for industry stakeholders the following questions have been developed and asked to the companies:

- 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.

4.2 Statistical results of the industry stakeholders

A total of **114 different companies** have been approached by the online survey and 48 of them replied.

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.

For confidentiality issues the results of the survey are shown only in an aggregated view and no company name will be shown in this part of the report.

In the following, form Figure 10 to Figure 21, the results of the survey for industry stakeholders are shown. The requested question has been intentionally shown in the diagram title to help the reader to better understand the meaning of the diagrams.

Based on these results a selection of the most relevant use cases has been performed. The selection of the use cases and the criteria used for the selection are explained in chapter 5.

Regarding the first more general part of the survey Figure 10 shows that more than 79% of the answers revels and interest in the noise barrier sector (road sector) and 63% in the noise barrier railway sector, while only 45% of the responses were coming from the safety barrier sector, and only 23% of the answers were from other road equipment. It is relevant to note that the sum of the answers reaches more than 100% because many companies are operating in more than 1 single sector.

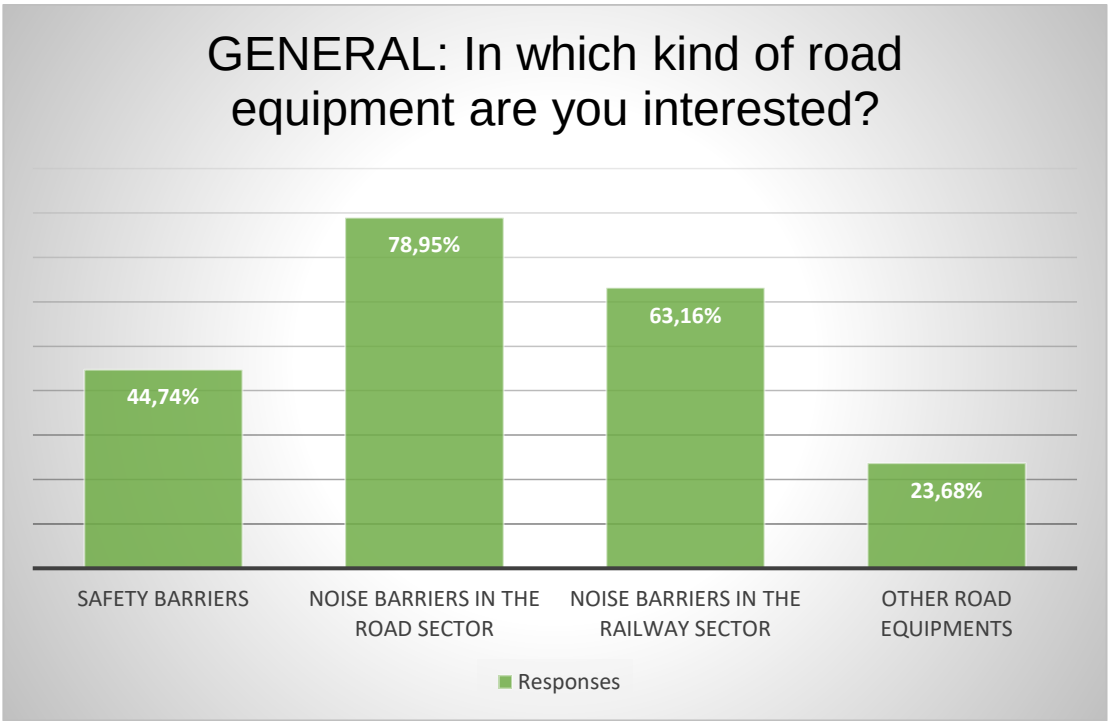


Figure 10: Answer to the question „In which kind of road equipment are you interested? "

Another general, but relevant question are the answers shown in Figure 11, where 34% of the interested are dealing with raw materials, while 63% are road equipment manufacturers and 26% are installer or contractors.

Figure 12 shows, that 66% of the companies are operating on a nation level, 63% are active on the European market and only 44% are interested in overseas markets.

Figure 13 clearly shows that more than the half of the company involved, even if they are in principle interested in the topic of sustainability, they are not familiar with the typical scheme to assess sustainability. Thus 56% of the companies answered "no" to this question, and only 46% seems to be familiar to this topic. The content can be found in the positive answers related to this question is shown in Table 19.

Figure 14 clearly shows that more than the 29% of the companies answered "no" to this question, and around 70% are familiar to this topic. The content can be found in the positive answers related to this question is shown in Table 20.

Figure 15 clearly shows that more than the 29% of the companies answered "no" to this question, and around 70% are familiar to this topic. The content can be found in the positive answers related to this question is shown in Table 21.

Figure 16 shows the distribution of the noise barrier types produced by the stakeholders answering to this survey while, Figure 17 shows the distribution of the safety barrier types produced by the stakeholders answering to this survey.

Figure 18 shows that only 8% of the companies answered "no" to this question, and around 91% are familiar to this topic. The content can be found in the positive answers related to this question is shown in Table 22.

Figure 19 shows that only 19% of the companies answered "no" to this question, and around 81% are familiar to this topic. The content can be found in the positive answers related to this question is shown in Table 23.

Figure 20 shows that only 31% of the companies answered “no” to this question, and around 69% are familiar to this topic. The content can be found in the positive answers related to this question is shown in Table 24.

Figure 21 shows that only 22% of the companies answered “no” to this question, and around 78% are familiar to this topic. The content can be found in the positive answers related to this question is shown in Table 25.

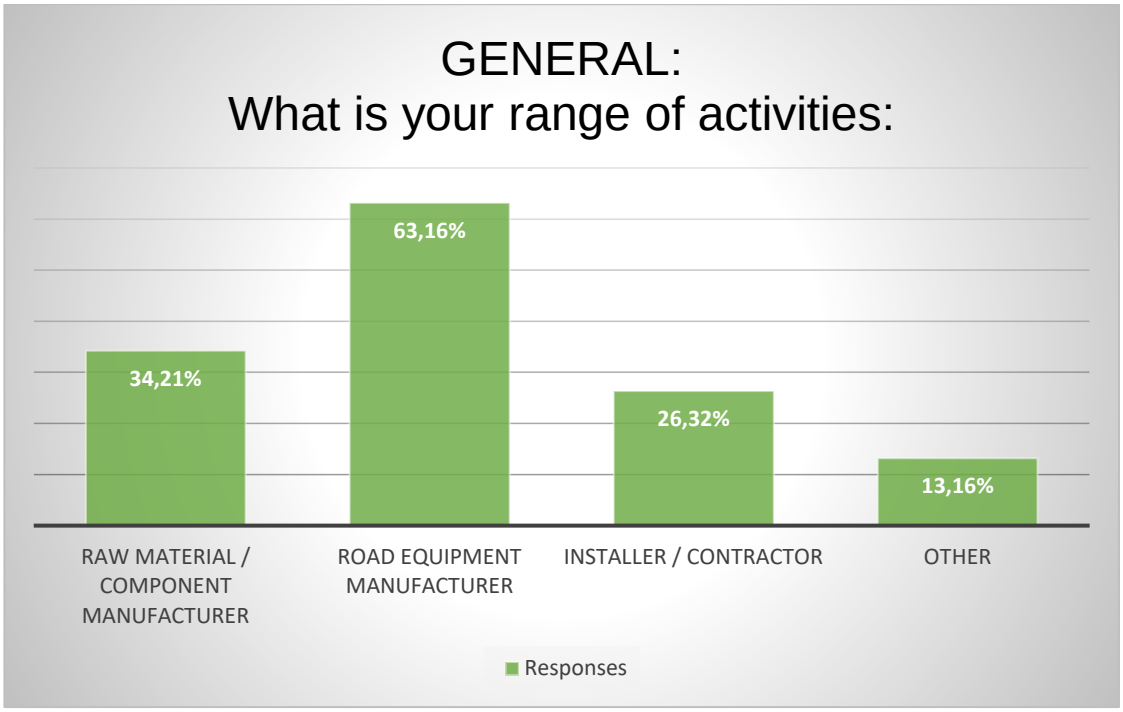


Figure 11: Answer to the question „what is your range of activities? “

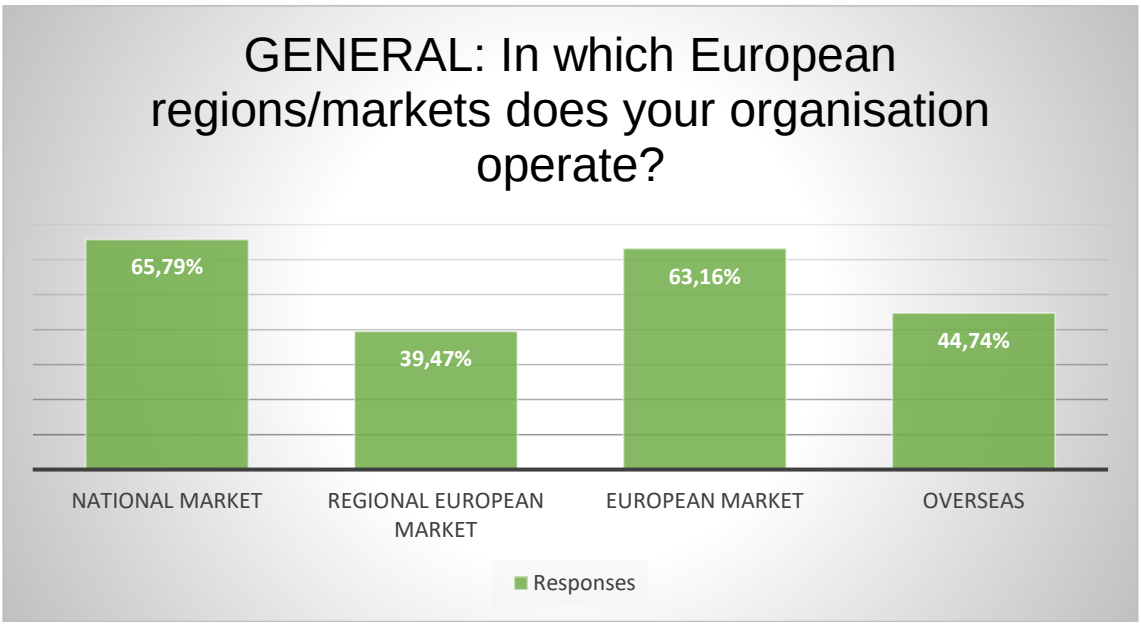


Figure 12: Answer to the question: „In which European regions/markets does your organisation operate? “

Figure 13: Answer to the question: „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 "

Table 18: Content of the positive answers to the question „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 "

CEN 1793- from 1 to 6, German EBA standards, ZTV-Lsw, and others.
Familiar with LEED schemes only for civil construction sector. We have no experiences for application of environmental sustainability schemes in road sector in Italy.
LEED / BREEAM / DGNB / HQE / Cradle to Cradle / Well.
Our products comply with CE 1793-1-2-3-4-5-6; fully recyclable, environmental sustainability, we offer Highspeed noise barriers 300km/h plus integrated PV.
LEED, BREEM, CAM.
We are only familiar with the Dutch MKI (environmental cost indicator).

LEED --> our noise barrier for construction sites is LEED certified.
Civil construction according to LEED procedure. In Italy products fulfilling CAM specifications.
LEED, EPD.
We participated to the QUIESST project with the university of Bradford.
CEREMA, ASQUER and IDRRIM.
LEED, BREEAM.
EPD.
We have a deep analysis on the environmental footprint for our products.

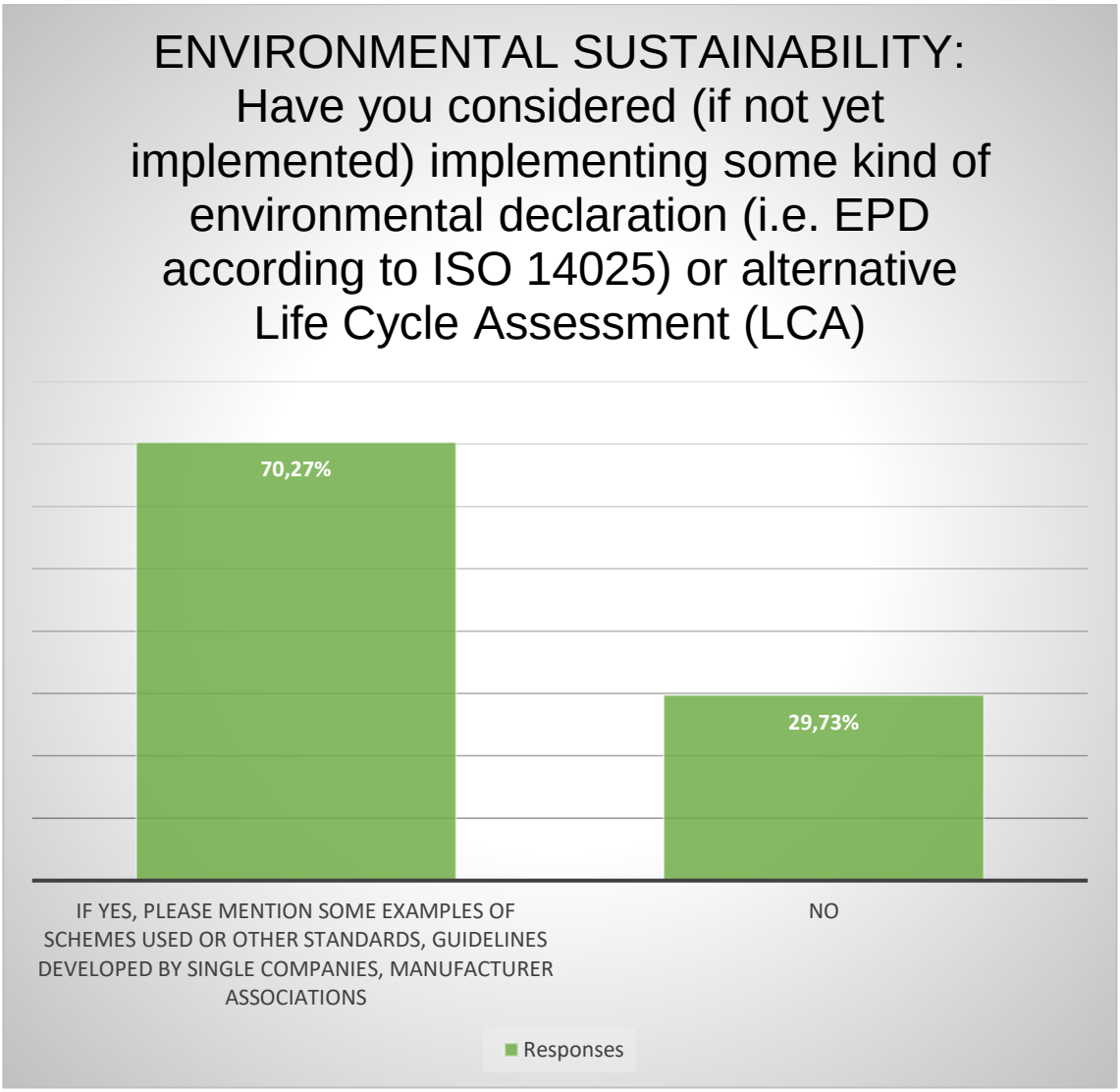


Figure 14: Answer to the question Have you considered (if not yet implemented) implementing some kind of environmental declaration (i.e., EPD according to ISO 14025) or alternative Life Cycle Assessment (LCA)? "

Table 19: Content of the positive answers to the question „Have you considered (if not yet implemented) implementing some kind of environmental declaration (i.e., EPD according to ISO 14025) or alternative Life Cycle Assessment (LCA) “

life cycle analyses for products; certification for company according ONR 192500.
Yes, we are considering a cradle-to-cradle certificate, as well as other assessments regarding our carbon footprint and impact on air quality and biodiversity.
We are currently developing EPDs/LCAs for our products with support from the Mineral Products Association our trade organisation, who have developed tools to support this process.
Currently we are preparing EPD according to ISO 14025, for some of our products (road restraint systems).
We have commissioned the Fraunhofer Institute for Environmental, Safety and Energy Technologie (UMSICHT) to investigate the environmental impact of efficient "Heat to coat" strip-galvanising process.
We have different life cycle certificates and physical performance.
Some technical working groups has been established in UNICMI to monitor European and Italian environmental legislation and to developed schemes for environmental declaration of products.
EPD available for raw material and for full safety barriers solutions.
EPD.
For some raw materials we use the nature plus declaration. For whole systems and raw materials, we use lifetime aging tests according to EN 14389-1/2.
We have life cycle assessment.
ABESCA as association is planning a PCR scheme to allow single manufacturers to prepare the EPD according to the ISO and EN standards.
We have EPD's for all our products.
UNI EN 14021 environmental labelling for acoustic tiles - construction tiles and for Light concrete and structural concrete for casting.
We have thought about it but have not activated it yet.
NF Environment 435 (Green labelling for road marking materials).
EPD according to ISO 14025. LCA leads to EPD.
CEN TC226 WG6 standards & FOROVIAL AENOR road equipment protocols (under development).
We made Life Cycle Assessment environmental-self declarations (comparisons) for 4 panels according to ISO 14021:2002 and issued by notified body CERMET Scarl (now named KIWA).
EPD generators providers with third party verification and publication at national program operators.
We've used Guideline of Plastic producers to create our Declaration.
it is our intention to proceed as soon as possible.

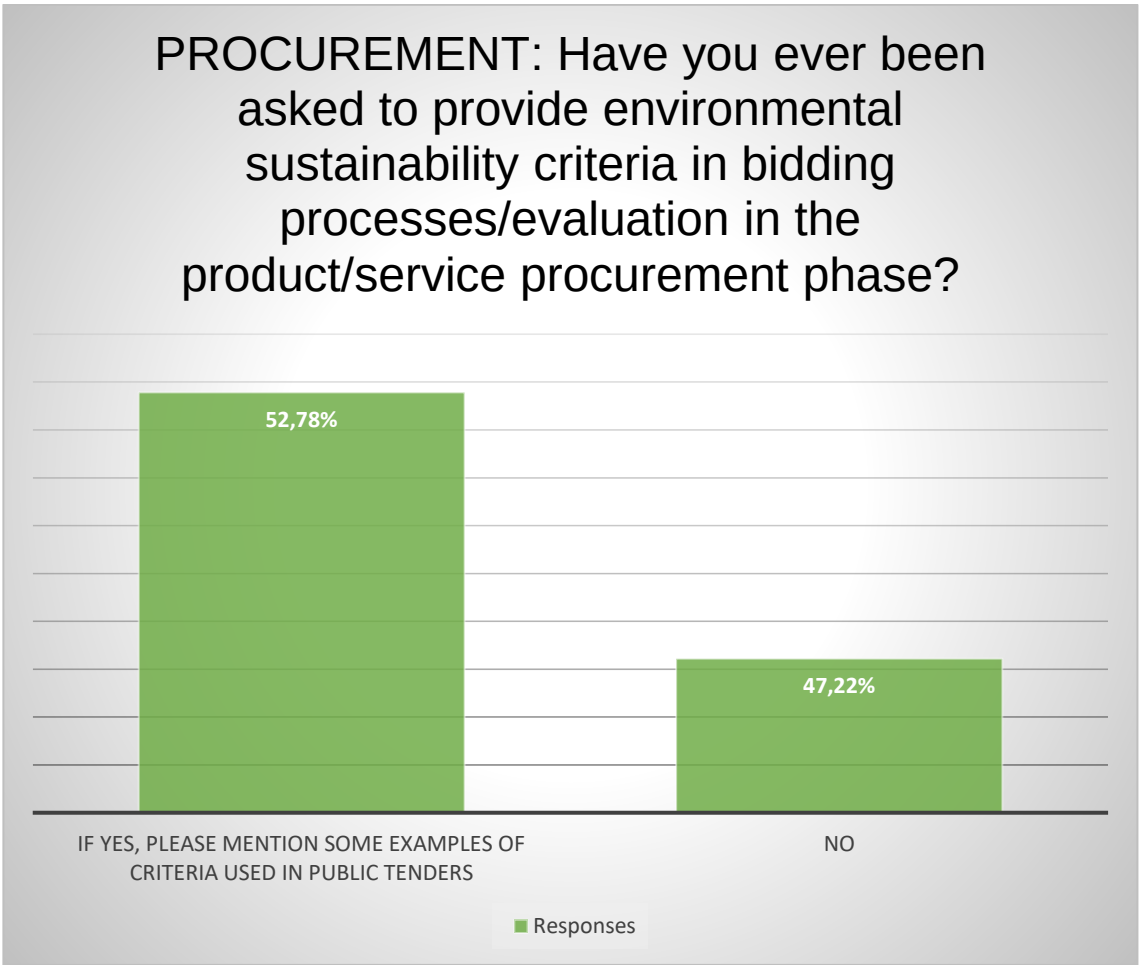


Figure 15: Answer to the question „Have you ever been asked to provide environmental sustainability criteria in bidding processes/evaluation in the product/service procurement phase? “

Table 20: Content of the positive answers to the question „Have you ever been asked to provide environmental sustainability criteria in bidding processes/evaluation in the product/service procurement phase? “

LCA`s.
No, but...It's coming. National Highways have already briefed the supply chain that environmental sustainability will become a mandatory in terms of product specification and pre-qualification criteria
On some of European markets we have been asked to provide documentation like EPD in order to participate in a public tender.
In civil construction sector the companies associated to UNICMI are currently asked to declare environmental characteristics when involved in public tenders or in private contracts based on public incentives. In road sector environmental sustainability declaration for products is voluntary. A national decree is expected in the first half of 2022.
Not for infrastructure projects with safety barrier but yes for building and bridges projects with other steel components.
EPD.

we had to prove where we plan to produce our products in respect to environmental impact (transport costs).
Rarely asked for. Criteria: required minimum lifetime. Nature plus declaration but not directly, only in the best bidder proceeding not in cheapest bidder for plus points.
as supplier we offer environmental sustainability.
Sigle manufacturers experienced GPP procedures but not for safety barriers applications.
MKI (Dutch) is often part of evaluation method. Since we are often part of a bigger project, we will have to give input about our projects.
LEED.
We participate a tender implemented according to MEAT procedures. The tender for noise barrier procurement.
Use of product technical evaluation to define the functional unit for LCA.
Only asked as a supporting document in Dutch market.
In some public tenders the environmental footprint is requested.

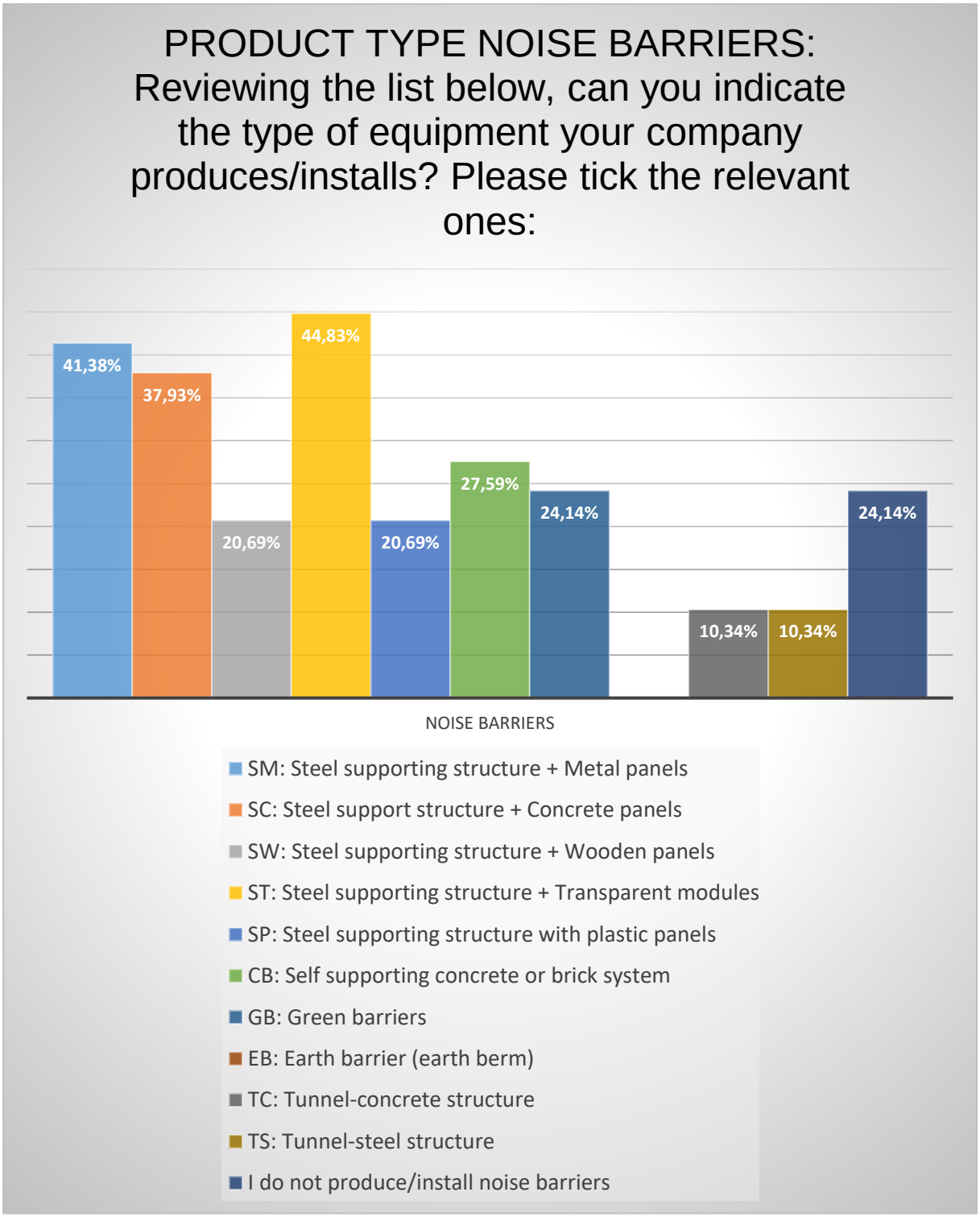


Figure 16: Answer to the question "Reviewing the list below, can you indicate the type of equipment your company produces/installs? Please tick the relevant ones (for noise barriers) "

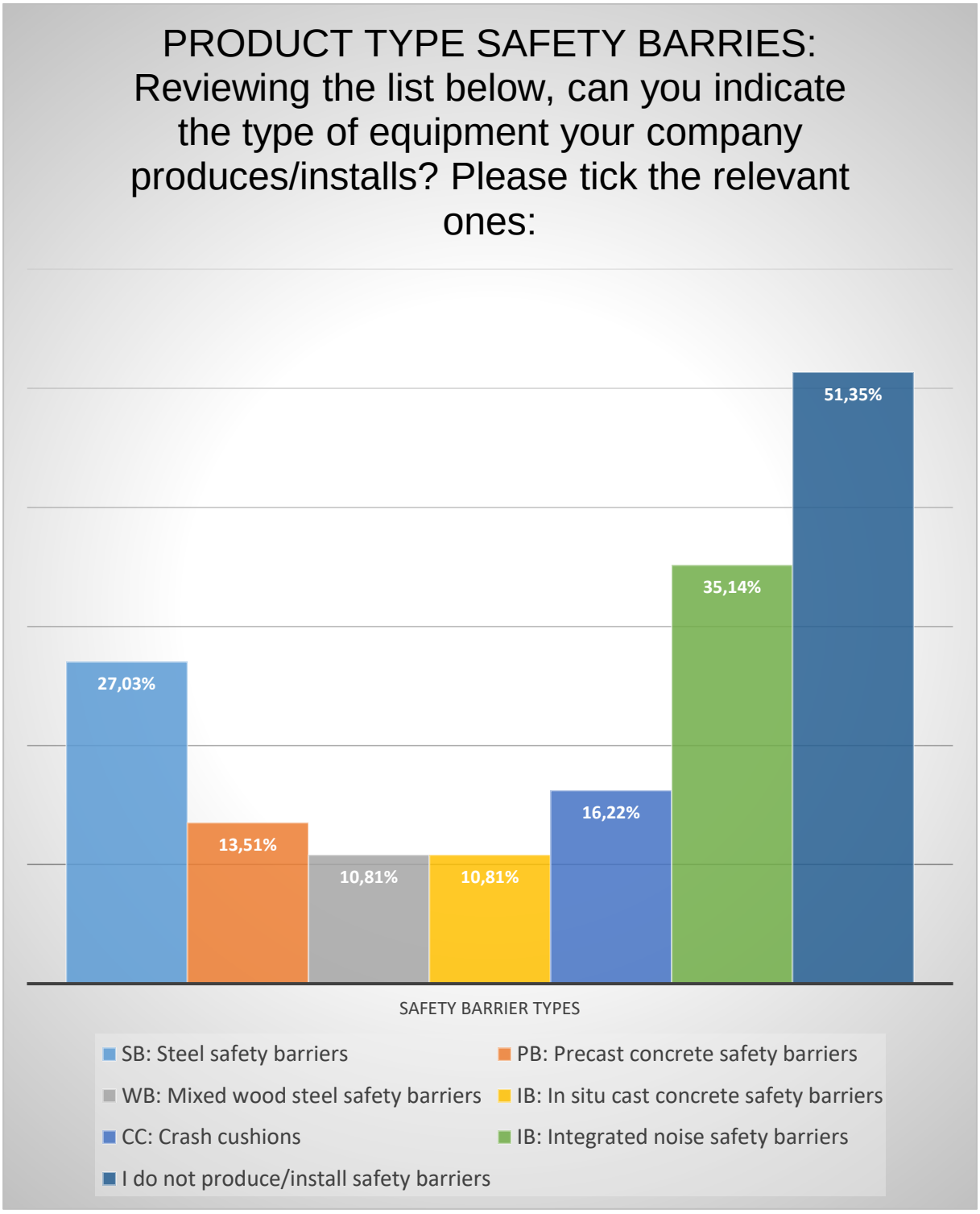


Figure 17: Answer to the question "Reviewing the list below, can you indicate the type of equipment your company produces/installs? Please tick the relevant ones (for safety and integrated barriers) "

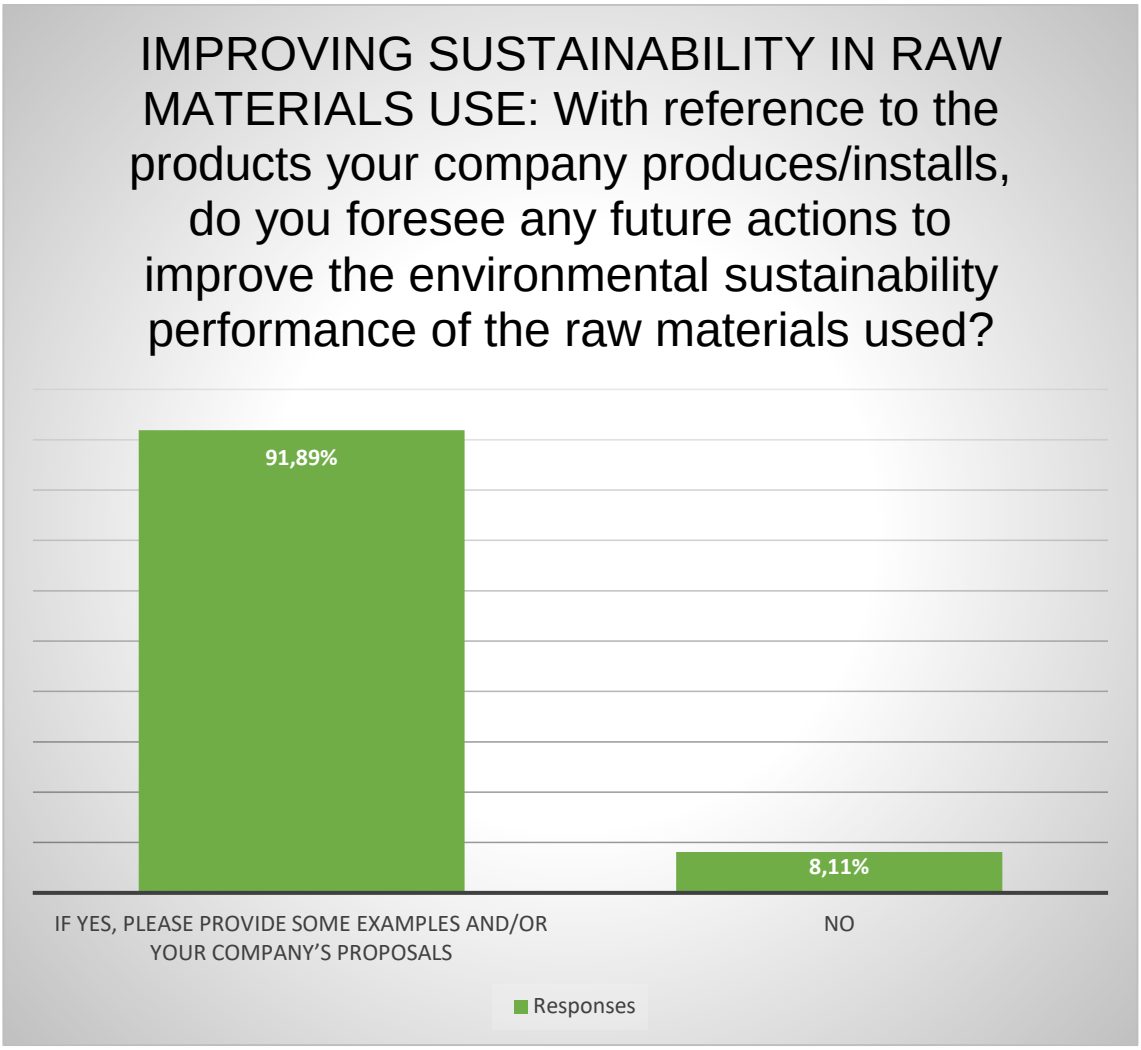


Figure 18: Answer to the question "With reference to the products your company produces/installs, do you foresee any future actions to improve the environmental sustainability performance of the raw materials used? "

Table 21: Content of the positive answers to the question „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? "

Using raw materials with better LCA results.
Our noise barrier system is already ecological. However, we have ideas on how it could be made even better - by changing the business model from selling a product to selling noise protection as a service.
Improving the carbon credentials of products by using less cement in concrete mixes or by using cement replacement technologies. Also, through innovation making products lighter with the benefit of decreasing the use of natural resources.
Stalpro Rail sx documentation as enclosure.
CO2-neutral production by 2025.
we use patented polyethylene foam as absorber.

Recycled Steel is a product currently improving sustainability performance of the product. Even in plastic sector products made by some associated companies are based on recycled materials. Solutions are explored for use of recycled materials in light concrete mixed design for noise panels.
EPDs to be the future vehicle to declare environmental performances in CE marking to answer BCWR 7.
development of new materials advances in concrete mis design optimisation of product specifications to ensure that requirements of projects do not require barrier performances higher than necessary so that the number of materials used is kept to a minimum.
using materials to reduce the impact on the environment use as much recycling material as possible.
For wood-concrete absorber we constantly improve the mixture recipe for a smaller CO2 footprint (especially cement).
our products are developed as full circle economy: PE whisper foam, solid aluminium, Corten-steel clean material assembled by interlocking geometry: no screws, no rivets, no glue, easy mounting, light weight transport, least maintenance.
Recycled rubber used in the concrete mix design. Also evaluating the use of milled asphalt according to national environmental legislation.
REducing the amount of concrete. Making diffracting elements from alternative materials that are more sustainable than steel/aluminum but have the same acoustic effect. For instance, using PE or Fiberglass Reinforced Plastics.
We follow a circular economy approach and try to work with environmentally friendly materials and recycled materials whenever possible, and the certification process allows.
Improve recycled content for aggregate and cement.
By replacing traditional concrete foundations with steel only foundations.
We intend to better evaluate sustainability for such products.
We manufacture absorption materials with a view to repurposing existing build infrastructure to comply with new needs and standards. For example, if a concrete reflective noise barrier wall exists, our material can be attached to the existing wall to turn it into an absorptive noise barrier wall to category A3 without replacing the entire wall. This is good for the planet. Our materials are designed with the view to eliminate unnecessary components for noise barrier wall manufacturers, for example there is no need for perforated metals, or plastic protective films when using our product. We supply the manufacturers of noise barrier walls with an independent report on the service life of our material to a 50-year minimum test. We provide an EPD based on our LCA to provide emissions assurances for our product once installed. We check the regulatory compliance for recycling our material and its packaging, and we assist the customer to find a recycling facility nearby the site of installation to minimize return to manufacturer shipping. We provide assurance that our material is recyclable under current norms within either their manufacturing state or the installation state. We have developed new versions of our products where we will take back the acoustic absorption fill material at end of life and recycle it into new material if the clients value closing the loop on noise barrier walls. We manage our company in such a way that our business will be around in 50 years to honour the commitments we make today.
Reduction of CO2 in Transport needs. Looking for local suppliers, recycling packages.
Noise barriers made with recyclable panels (glass, metal); recyclable noise absorbent

internal mat; reduce the purchasing distance of raw material of the building site from the manufacturer's factory.
Use of recycled concrete aggregates in the concrete mix. Efforts of different cement industries towards climate-neutrality in 2050 - see different Road Maps (CEMBUREAU + national associations)
Buy carbon neutral raw material.
Our product can be 100% recycled, we want to reach a much higher level of use of that "second hand" item.
produce other items for the infrastructure sector with recycled plastic materials.

Figure 19: Answer to the question „With reference to the products your company produces/installs, do you see possible actions/measures to improve the environmental performance in the manufacturing phase? "

Table 22: Content of the positive answers to the question „With reference to the products your company produces/installs, do you see possible actions/measures to improve the environmental performance in the manufacturing phase? "

Electric vehicles: other than that, our processes are very clean thanks to the materials we use.
Increase the volume of re-cycled materials in concrete mixes.

We plan to introduce in the future more and more renewable energy sources in manufacturing process. It shall improve sustainability in manufacturing process.
Based on the LCA of Fraunhofer we work on it.
avoid dirty materials (glass wool, mineral wool, paint) we use solid aluminium and solid Corten steel sheets we use clean recycled PE foam as absorber, and we assemble modules without glue, rivets, or screws
Some actions are explored by the companies, but the perspective is for a low impact on the overall environmental performance.
use steel with higher resistance to decrease impacts.
Constantly improving moulds for concrete panels for optimized needed construction time and other applications. e.g., instead of plastic connectors we changed to glue.
intelligent Design, intelligent engineering, longevity design clean Material, light construction optional screw foundations.
All manufacturers are improving energy consumption in casting processing.
We do not manufacture ourselves at the moment. However, we try to choose our supplier/manufactures according to quality and environmental standards.
Minor improvement in energy consumption.
Steel foundations produce less CO2 than concrete solutions by more than 50% because less material is used when using steel.
We intend to check these possible criteria in our customers FPC in the future.
Yes! We actively partner with noise barrier wall manufacturers to reduce their emissions footprint and make the finished product more sustainable. We are constantly striving to improve our footprint through a net zero target, science-based targets, greenhouse gas intensity reductions, renewable energy and water use, diverting waste from landfills, achieving zero harm, creating a diverse and equitable workplace culture.
Optimizing energy needs and its origin, improving sustainability concepts in each phase of the production process.
reducing the CO2 due to internal transports, by purchasing from local suppliers of raw materials if available or purchasing from suppliers 'factories that are nearer to the building site.
Use of recycled materials in the concrete mix Use of low-carbon cements.
Use of green energy.
We're evaluating a reduction of natural gas costs.
we are considering designing the production of our products with solar energy.

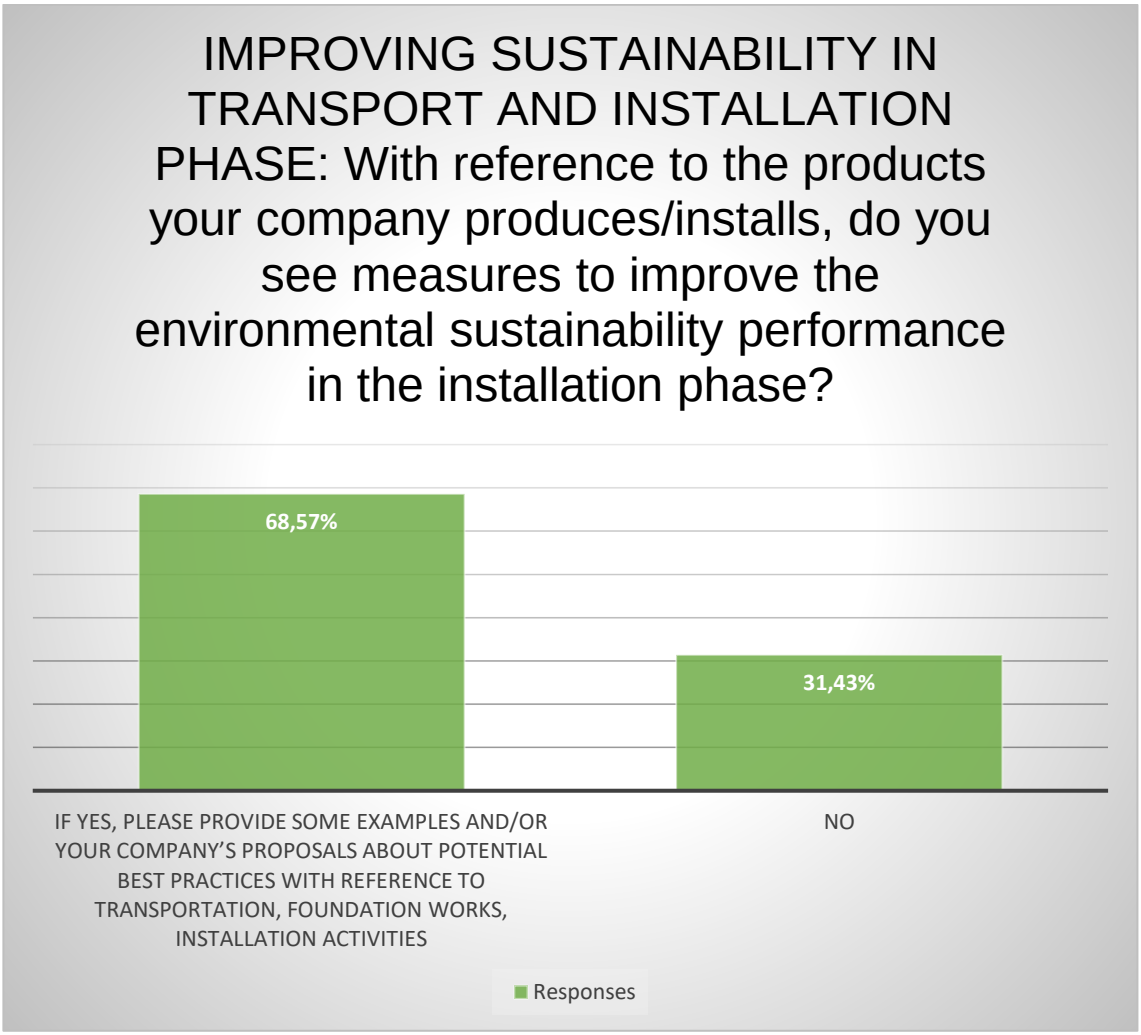


Figure 20: Answer to the question „With reference to the products your company produces/installs, do you see measures to improve the environmental sustainability performance in the installation phase? "

Table 23: Content of the positive answers to the question „With reference to the products your company produces/installs, do you see measures to improve the environmental sustainability performance in the installation phase? "

Electric vehicles; ecological sealings.
Through product innovation making products lighter and smaller in cross section which allows more product per truck to be delivered and makes the individual precast units easier to handle and install. We are also looking at more innovative foundations that use less material and are easier to install and involve less 'muck' disposal to land fill.
light weight, ready to install standardized modules, installation from mobile platforms; if possible, we suggest screw foundations; qualified design of abatement measurements; trained acoustic planners with topographic expertise.
Most of the companies are exploring solutions to minimize the impact in transport and construction phase. I.E., new foundation systems for noise barriers, installation procedures of heavy concrete products.
production as close as possible to project.

Because of mobile moulds we always seek to manufact as close to the site as possible to reduce transport.
reduced height by refracting active top light weight elements, fast mounting, easy transport screw foundations.
Some products are reducing the need of heavy foundation works. Reduce of traffic disruption and duration of works and soil cementification.
lighter materials reduce the amount of transport needed. In general, by reducing the height of noise barriers we reduce the amount of transport and installation needed.
Aware noise barrier system based on acoustic tiles can lead the strong diminution the transport. This allows un improvement sustainability compared to traditional concrete acoustical panel.
less transports (easily stackable steel sheets) and faster execution.
Same as for FPC including circular economy.
In moving to our material over mineral wool, we offer noise barrier wall manufacturers the opportunity to move from 100-120kg/m3 density of materials used, to 25kg/m3 density of materials used for category A3 acoustic absorption performance. This enables customers to load more in a single truck or container movement than previously possible. In addition, over concrete based barriers, up to 2000m2 of absorption materials can be moved in a single truck movement vs <200m2.
Stocks gestion, packages reusing.
trying to make continuous installation periods for labour and shipping full trucks to building site so that to reduce the trips of personnel and reduce the number of transports to the site.
Reduced emission of vehicles.
low emission transportation vehicles.
Our products are very quick to install (therefore use of vehicles for less time) and have the possibility of being integrated with the addition of photovoltaic panels for the direct production of energy.

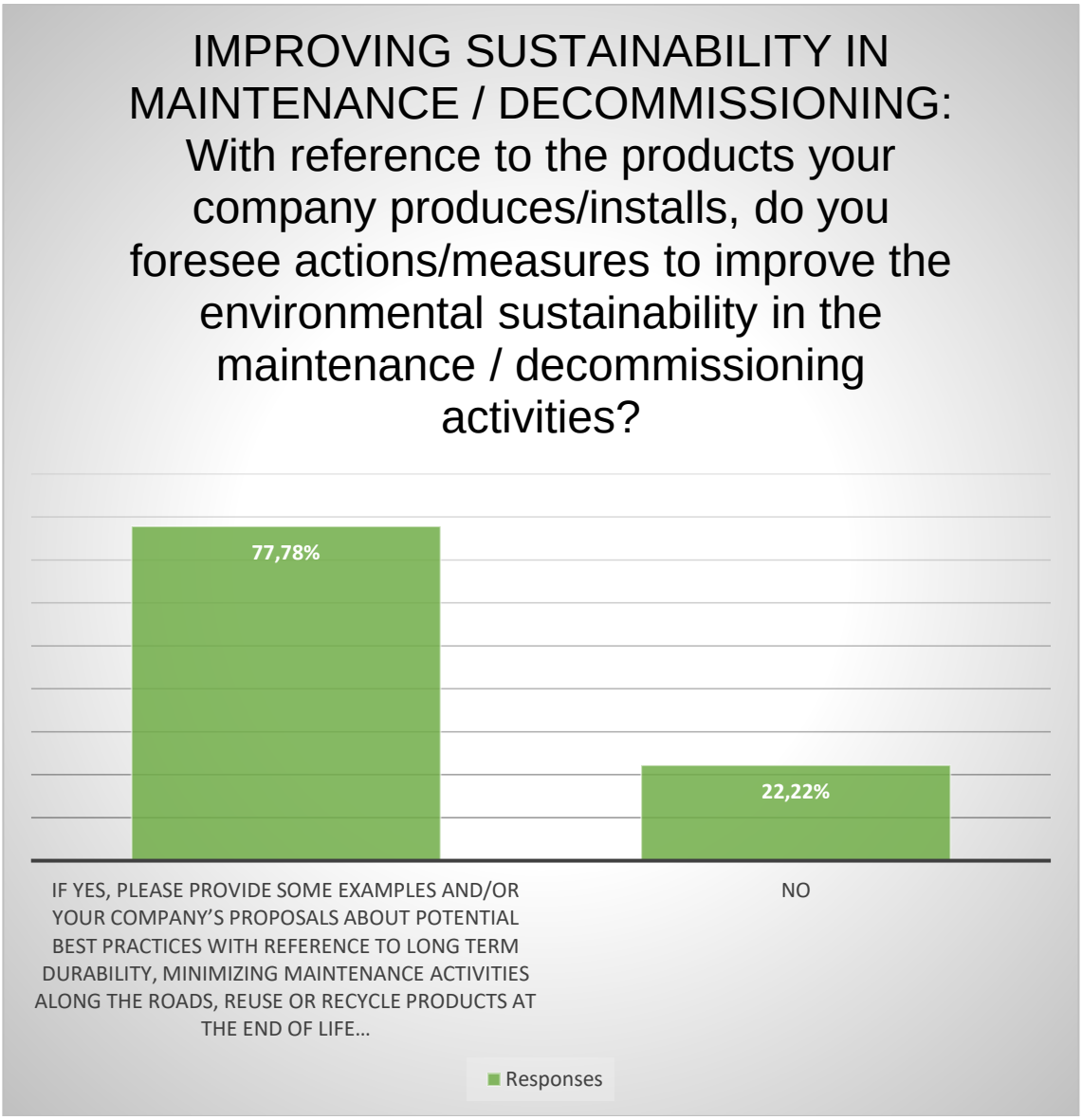


Figure 21: Answer to the question „With reference to the products your company produces/installs, do you foresee actions/measures to improve the environmental sustainability in the maintenance / decommissioning activities? "

Table 24: Content of the positive answers to the question „With reference to the products your company produces/installs, do you foresee actions/measures to improve the environmental sustainability in the maintenance / decommissioning activities? "

higher quality - increasing the life cycle - a lot of regional different; it depends on the investment.
No plants to minimize maintenance activities and costs; Reuse & recycle products at the end of life; Looking into providing a noise protection as a service option in the future.
As a supplier of concrete barrier to the strategic road network, we already must provide products with a 50-year serviceable life. From a whole life cost point of view this offers significant benefits over steel guardrail systems. For the central reserve concrete barrier must be rigid and not require maintenance or repair following an impact. This is subjective

of course to the type of impact; however, it cannot be denied that a concrete barrier left in the elements does not require maintenance in its serviceable life. At the end-of-life concrete barrier can be crushed and re-cycled into other concrete products or in the case of precast units used in other barrier applications where the vehicle restraint aspects of performance are not necessary e.g., temporary gate/property access security.
Barriers are safety device and declared parameters are coming from the quality of steel, that is why limited possibilities of reuse of material exist.
We insist on clean material and clean assembly; solid supporting structure (heavy duty design), avoiding chemical bonding, screws, rivets to assure final dis mounting and disassembling oriented to 100% recycling and least maintenance.
Reducing maintenance is a target for all associated companies. I.E., improving galvanisation process for steel safety barriers, use of reinforced transparent panels in noise barriers, special treatment of wood to prolong the life of the product.
Metallic coated steel with longer durability & potential guarantee on corrosion resistance - Material is already recovered and recycled.
improve recyclability of the raw materials.
We use 100% recyclable raw materials as Absorbers. e.g., Wood concrete and PE.
full recyclability and longevity of modules, no galvanizing, no paint; anti-corrosive structure: Corten-steel; no mineral wool, no concrete, no wood, but self-standing PE Whisper foam slabs (30kg/m³!); repairability on site, least maintenance.
Concrete safety barriers don't need lot of maintenance activities because of high durability of the Material itself. Procedures had been implementing to separate single components (steel, aggregates and cement) in decommissioning phase.
Especially with end of life our products can be removed easily since no foundation is needed. It can be decomposed to steel and concrete which can be recycled. Other materials like PE could be interesting since the can be reused as the same product again. One of the biggest advantages of our products is that they can be relocated easy. So, if the situation changes (for instance an extra lane is added), the products can be moved easily to work in the new situation. Where traditional noise barriers would have to be demolished.
Since our products are newly introduced to the market the topic of maintenance is a very important to us, that we closely monitor. We chose materials and assembly processes that ensure long life-spans.
Acoustic tiles can be replaced on the barrier in stalled in situ. Material can be full reuse.
With our solution it is possible to remove and reuse or completely recycle the foundation as it is 100% steel, without demolition or transport to landfill.
Independent testing to show a 50-year service life, with no maintenance. Decommissioning and end of life recycling facilities are in most major cities for our product, vs competitors' materials which need to be returned to manufacture location.
Improving products designs to reduce maintenance needs.
if noise barriers are made with recyclable panels (i.e., glass, metallic panels) the sustainability is easier and better for the environment.
Concrete safety barriers mostly need no or very little maintenance and have a very long service-life. In this way, they are the most durable and sustainable solution.

reuse of existing parts.
We can accept all our used or substituted product incoming from customers and authorities who decide to change or renew their noise barriers.
our panels do not need maintenance, have an expected durability of over 20 years and are ultimately completely recyclable.

4.2.1 Main findings of the PROCEEDR survey for industry stakeholders

Summarizing, the main findings of the PROCEEDR Survey for industry stakeholders are the following:

- About **50% of the industry stakeholders are not familiar with schemes used to assess environmental sustainability of the whole construction process** e.g., LEED, BREEAM, DGNB/ÖGNI or specifically for road infrastructure.
- About **50% of the companies have ever been asked to provide environmental sustainability criteria** in bidding processes/evaluation in the product/service procurement phase.
- **70 to 90% of the companies tries to improve the sustainability** of the product concerning selection of the raw material, manufacturing process and maintenance.
- The results indicates that the interest for improving the sustainability of the products exists, however, there is a **lack in knowledge related to existing tools**, which can be improved by adding documentation concerning sustainability assessment in bidding process.

Finally, the topic of sustainability in the noise and safety barrier sector is rather new, the noise barrier sector seems to be more advanced in considering some of the sustainability criteria and trying to improve their products. The main reason could be that the **safety barrier sector is more forced to the functional requirements** and safety is recognised to be **a fundamental need in our society**, on the other hand the noise topic is more related to the environmental protection and probably also for this reason the manufacturers are in general more sensitive to this topic.

Furthermore, a harmonized approach regarding sustainability criteria in the noise and safety barrier sector can only be reached with a **top-down approach**, by asking for specific KPIs with the inclusion of minimal requirements in public procurements.

5 Selection of relevant case studies for further research activities

The analysis of the PROCEEDR survey for industry stakeholders made evident that sustainability is a rather new topic and only to some extent is a target for the industrial stakeholders.

Nevertheless, **innovative materials or special treatments of materials** in use to prolong durability is the focus of sustainability policy of many companies. In many cases the innovation for noise and safety barriers is represented by the adoption of technologies and materials used in other sector of construction products.

Other ways to pursue sustainability targets are represented by **solutions able to minimize maintenance activities**. Traffic disruption is the cause of secondary impacts that must be considered especially on main roads and motorways.

It is always the case for noise barriers and in many cases for safety barriers that foundation works or installation on existing structures require civil works having a relevant influence in the overall sustainability score. Some solutions presented show how these **additional works can be minimized**. In the noise barrier sector, a more efficient and sustainable approach is also represented by the innovative proposals aiming to **improve the acoustic effectiveness**.

Finally, most of industrial stakeholders made evident **how the materials and products proposed can be recycled at the end of working life**. Due to the characteristics of these construction products, reuse is less considered as a possible option.

In this chapter a short list of relevant case studies is provided. The selection in based on the results of the survey and case studied have been selected with the aim of covering the **entire life cycle.** In addition to noise and safety barriers manufacturers, **raw materials suppliers** have also been considered.

Preference has been given for products and solutions that are **common between various manufacturers**.

Another choice criterium is represented by the need of maximising **geographic distribution** of the selected proposals as the type of products circulating on the European market are not uniform due to climate differences and the different policies implemented.

For safety barriers mainly **materials and final products** area considered. For noise barriers the following three elements are covered:

- **foundations,**
- **structural elements,**
- **acoustic elements.**

With reference to the above criteria the following tables show the selection of relevant roadside infrastructures solutions considered for further investigation in the next activities of PROCEEDR. For each chosen solution a short summary of the technical information's is shown. The main claims raised by the manufacturer for sustainability are listed and a scheme where the expected impact of different life cycle stage is shown.

The list of the following 11 case studies provided hereafter, fulfils milestone M1.2 "Selection of relevant roadside infrastructure solutions and methodology or ranking criteria for product selection" and provides the ground for the choice of specific case studies to be further investigated in next steps of present research.

5.1 Case study on sound absorbing materials for acoustic cassette panels

Proposed by: SEALEDAIR

The company Sealed Air proposes a high-performance polyethylene foam derived from applications in the food packaging sector. It is a durable material, acoustically 'soft' eliminating the problem of hard reflective surfaces that contribute to reverberation and echo.

This material can be used to fill acoustic cassette to ensure sound absorption properties. Given the weathering resistance of the material the external perforated surface of the cassette can be avoided.

Description: innovative sound absorbing material for cassette acoustic panels.

Referred to: noise barriers /acoustic element.

Main claims with reference to sustainability:

- Improved raw material for acoustic components of noise barriers
- Spin off from other industrial sector (food packaging)
- Sustainability policy well established in the company
- EPD already available

Key modules within the whole Life Cycle

Product Stage			Construction Process Stage		Use Stage							End-of-Life Stage				Benefits and loads beyond the system boundary		
Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D

5.2 Case study on galvanisation protection of steel surface

Proposed by: WUPPERMANN_CRM Group (ARCELOR MITTAL)

Wuppermann GmbH Austria and CRM Group Belgium are leading companies in the sector of galvanization processes to improve the corrosion resistance of the steel material.

The companies are proposing on the market pregalva steel or road restraint systems manufacturing.

The validation of the galvanization systems is ongoing in different Euopean countries.

Description: pregalvanised steel for vehicle restrain systems.

Referred to: safety barriers.

Main claims with reference to sustainability:

- Improving the durability and the sustainability of the steel used for safety barriers
- Shortening the production chain
- Sustainability policy well established in the company
- EPD already available.

Expected effect on EN 15804 modules within the whole Life Cycle

Product Stage			Construction Process Stage		Use Stage							End-of-Life Stage				Benefits and loads beyond the system boundary		
Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D

5.3 Case study on timber safety barriers

Proposed by: TERTU, MARGARITELLI

Tertu is a manufacturer of steel backed timber guardrail market.

Margaritelli is involved in the same business proposing the use of laminated wood.

The companies present a large mixed wood & steel guardrails range.

Steel components are ensuring high containment levels while the wood components help the compatibility mainly to rural or mountain landscapes.

Description: timber used for safety barrier.

Referred to: safety barriers.

Main claims with reference to sustainability:

- Raw material type
- Treatments for raw material (wood) to ensure long term durability
- Sustainability policy established in the company.

Key modules within the whole Life Cycle

Product Stage			Construction Process Stage		Use Stage							End-of-Life Stage				Benefits and loads beyond the system boundary		
Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D

5.4 Case study on plastic acoustic cassette panels

Proposed by: NOISE srl

Noise is a company specialized in the design, production and construction of sound-insulating and sound absorbing panels made of plastic material.

The acoustic cassette is made from recycled PVC mainly resulting from the recycling of windows frames.

The inner material is a recycled polyester previously used for bottles or other packaging applications

The product offers high acoustic and aesthetical performances along with an easier and fast installation rate.

The material is idoneous for further recycling at the end of the working life.

Description: acoustic cassette panels in recycled PVC.

Referred to: noise barriers.

Main claims with reference to sustainability:

- Raw material (both PVC and recycled polyester)
- Spin off from other industrial sector (windows frame)
- Sustainability policy considered (not yet established)
- Other companies with similar product (Deceuninck)

Key modules within the whole Life Cycle

Product Stage			Construction Process Stage		Use Stage							End-of-Life Stage				Benefits and loads beyond the system boundary		
Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D

5.5 Case study on integrated noise and safety barriers

Proposed by: DELTABLOC – REBLOC - CIR AMBIENTE - UNICMI

Deltabloc GmbH is part of a group involved in concrete manufacturing and specialized in safety and noise barriers.

The company deals with a wide range of products: from permanent and temporary road restraints to crash barriers and noise barriers.

Similarly, Rebloc GmbH is active in the field of concrete products for road applications.

UNICMI is the Italian association of road equipment's manufacturers; different solutions of steel based integrated noise and safety barriers are proposed by the associated companies.

Description: integrated noise / safety barrier**.**

Referred to: noise barriers.

Main claims with reference to sustainability:

- Raw material (both steel and concrete solutions)
- Reduced space used on the road
- Sustainability policy established in some companies.

Key modules within the whole Life Cycle

Product Stage			Construction Process Stage		Use Stage							End-of-Life Stage				Benefits and loads beyond the system boundary		
Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D

5.6 Case study on transparent noise barriers

Proposed by: ROEHM

Röhm GmbH products are all derived from acryl sheets made through an extrusion or casting process.

The raw material is a recycled monomer.

The polymer obtained is ensuring the mechanical, acoustic ad long term durability properties.

This product is widely used in noise barrier to ensure the transparency often required by citizens for aesthetical reasons.

The company has developed various customized solutions for noise barrier applications.

Description: acryl transparent sheets for noise barriers.

Referred to: noise barriers.

Main claims with reference to sustainability:

- Raw material (recycled acryl)
- Sustainability policy well established
- EPD already available
- Other companies with the same product (i.e. Akrypol).

Key modules within the whole Life Cycle

Product Stage			Construction Process Stage		Use Stage							End-of-Life Stage				Benefits and loads beyond the system boundary		
Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D

5.7 Case study on foundation system integrated with the supporting structure of noise barriers

Proposed by: FONSIDER - KRINNER

FONSIDER Srl is a company proposing a controlled vibrodriving steel foundation solution that allows its use for all types of steel structures included noise barriers.

KRINNER GmbH is a company proposing a steel screw system to realize ground foundation for several applications. It can be applied for noise barriers installed on soft ground.

Both systems allow the realization of ground foundation by avoiding the construction of a concrete kerb and deep foundations piles.

Description: special foundation for noise barrier.

Referred to: noise barriers.

Main claims with reference to sustainability:

- Raw material
- Innovative and fast construction method
- Less ground cementification
- Sustainability policy not yet established.

Key modules within the whole Life Cycle

Product Stage			Construction Process Stage		Use Stage							End-of-Life Stage				Benefits and loads beyond the system boundary		
Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D

5.8 Case study on noise barriers equipped with PV modules

Proposed by: KOHLHAUER - FORSTER

Kohlhauer GmbH, is a service provider for noise and environmental protection technology.

Forster GmbH is a company manufacturing steel-based products for road applications

Both companies develop and produce noise protection elements with added value for the environment, climate and use of resources.

Description: noise barrier equipped with photovoltaic modules.

Referred to: noise barriers.

Main claims with reference to sustainability:

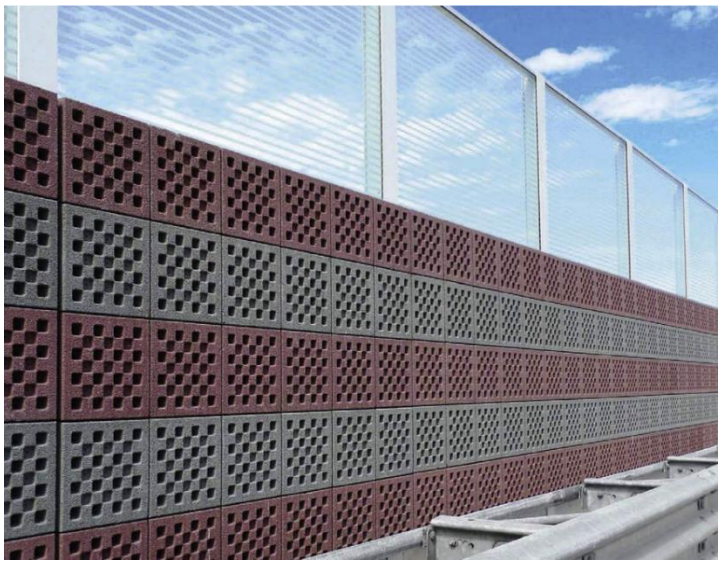
- Various solution for innovative noise barrier
- Multifunctionality
- Sustainability policy established.

Key modules within the whole Life Cycle

Product Stage			Construction Process Stage		Use Stage							End-of-Life Stage				Benefits and loads beyond the system boundary		
Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D

5.9 Case study on sound absorbing concrete tiles

Proposed by: EDILLECA – RUNCOBAR – VELOX - CAPREMIB



Edil Leca is a manufacturer of blocks of various sizes made from Leca expanded clay, a material that offers several applications and technical solutions for constructions products.

RUCONBAR (Rubberised Concrete Noise Barriers) is a project under the umbrella of the Eco-Innovation initiative and Executive Agency for Competitiveness and Innovation Framework Programme (CIP).

Velox is a company that produce contemporary and high quality building products and systems by combining technical quality with innovative technology.

Capremib is a manufacturer specialised in prefabrication of concrete products for building and public works.

Description: sound absorbing tiles for concrete noise barriers.

Referred to: noise barriers.

Main claims with reference to sustainability:

- Raw material
- Construction system for concrete noise barriers.

Key modules within the whole Life Cycle

Product Stage			Construction Process Stage		Use Stage							End-of-Life Stage				Benefits and loads beyond the system boundary		
Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D

5.10 Case study on bio-based noise barriers

Proposed by: REEDuce

REEDuce deals with noise protection technologies. The company produces ecological noise barrier made of reed, thermowood and clay reduces noise from roads and other noise sources effectively and sustainable.

Description: noise barrier from vegetation.

Referred to: noise barriers.

Main claims with reference to sustainability:

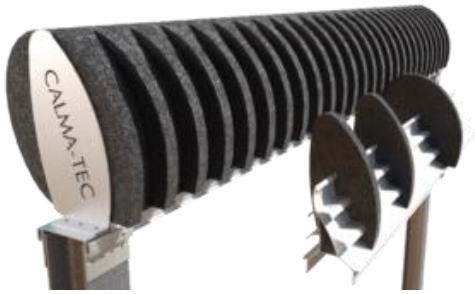
- Raw material
- Sustainability policy established.

Key modules within the whole Life Cycle

Product Stage			Construction Process Stage		Use Stage							End-of-Life Stage				Benefits and loads beyond the system boundary		
Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D

5.11 Case study on innovative systems for noise protection

Proposed by: PHONONIC VIBES – CALMA-TEC - 4 SILENCE - WAVEBREAKER



Phononic vibes exploits the use of special sound-absorbing insulating panels. This patented technology is based on the development of metamaterials, i.e. artificial materials with unique mechanical properties, which differentiate them from other materials.

Calma-Tec noise reduction systems are solutions against road, industrial and railway noise. The product is based on a special polyethylene foam to obtain reflection-free noise absorbing material.

4silence developed noise reducing devices acting on the diffracted noise. These products can be installed on the noise barrier top or even on the ground level.

Wavebreaker produces a passive "sound-trap" to be installed on the top edge of the noise barrier to enhance its perfomance.

Description: highly innovative products to improve noise barrier efficiency

Referred to: noise barriers

Main claims with reference to sustainability:

- Innovative solutions for noise barriers
- Sustainability policy implemented

Key modules within the whole Life Cycle

Product Stage			Construction Process Stage		Use Stage							End-of-Life Stage				Benefits and loads beyond the system boundary		
Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D

6 Summary and Outlook

The main goal of this document was to build the basis for the future work to be done in PROCEEDR together with the first deliverable D1.1 on existing LCA/LCCA-tools and roadside infrastructure solutions including a SWOT analysis of existing tools.

The main scope of the work was to perform 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 was collected throughout Europe using a dedicated online questionnaire, achieved with in M1.1 (Questionnaire and interviews with relevant stakeholders carried out). In addition, data and information collected in past and current projects were considered.

After a first general introduction given in Chapter 1, explaining research needs and the aim of PROCEEDR, the specific objectives of WP1 and the approach on sustainability are explained with focus on noise and safety barriers.

Chapter 2 describes the status of the European regulations and the current sustainability approach in the field of noise and safety barriers, answering to the question “how the environmental and sustainability topics have been dealt within past and current construction projects in the field of nose and safety barriers.

Chapter 3 gives an overview of the noise and safety barrier types commonly used in Europe and suggest a tentative classification for the most used noise and safety barrier types in Europe. A schematic template for inserting relevant information on the whole life cycle has been developed and for every noise and safety barrier type the template was filled.

In Chapter 4 the development of the survey, the results of the survey and a statistical analysis of the survey for industry stakeholders is shown. Based on these results the selection of relevant roadside infrastructure solutions is performed and described in Chapter 5.

As a final output of this work package a practical guideline for assessing the use of different material in roadside infrastructure products will be provided with report D1.3 “Practical guideline with a recommendation for industrial stakeholders to assess the use of different materials in roadside infrastructure”.

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ANNEX A - Survey for Industry Stakeholders

PROCEEDR - Optimising Resource Use for Roadside Infrastructures

Questionnaire for Industry Stakeholders

October 2021

Dear Stakeholder,

we kindly ask **20 minutes of you time**, to address the topic of **sustainability of the road equipment** in the construction sector, which is becoming a very important aspect for the product choice of the most innovative National Road Authorities today.

Roadside infrastructure today comprises many different road equipment increasing the volume of materials needed for constructing roads. In the last few decades, the number of products used alongside roads has been widely increasing and will continue to increase as technology progresses. As a consequence, road infrastructure requires extensive natural resources and is a major generator of the waste. Without intervention, this is only expected to increase.

Therefore, **the national road authorities are leading an initiative to encourage the recycling and reuse of materials, and the use of renewable and biodegradable materials**. CEDR (the Conference of European Directors of Roads) has commissioned an international **research project PROCEEDR to address the environmental sustainability issues of the roadside infrastructure**. Among road equipment, noise barriers and safety barriers have been deemed most relevant. Both have been chosen to serve as study objects of this research project to help the national road authorities to reduce their environmental impacts and to contribute to a circular economy.

As part of the project we are carrying out stakeholder consultation to learn more about the products and solutions developed with the aim of improving environmental sustainability. We are getting in touch with you based on your ogranisation's involvement in this this field and the value you could bring to our project. We would greatly appreciate your input into our questionnaire.

We kindly ask you to send us your answers **by November 14th, 2021.**

More information about the PROCEEDR project can be found in the attachment with a project summary.

With thanks in advance - **The PROCEEDR team**

Address for sending additional information or documents: info@erf.be

Permissions and consent

If you take part in this survey we will need to store your responses and your contact details for further communication on this project - please note that you will have the option to select your desired level of involvement, including not being contacted again.

Your responses and contact details will be collected and handled in accordance with the PROCEEDR privacy notice which can be found in the Annex. PROCEEDR aims to use your data responsibly and in line with GDPR requirements.

Your responses and contact details may be shared with other PROCEEDR project consortia partners (Chalmers University of Technology, AIT - Austrian Institute of Technology GmbH, TRL Ltd, ERF - European Union Road Federation) for analysis and potential further consultation. A data handling agreement will be signed between ERF and all consortia partners prior to sharing your data.

If you wish to participate in this survey we require your consent to collect your survey responses and contact data, and share these within the PROCEEDR consortium.

Please let us know if you wish to continue with the survey. *

- [ ] I am happy to continue with the survey
- [ ] I do not wish to continue with the survey (please consider telling us why in the comment box below)

If you wish to participate in this survey we require your consent to collect your survey responses and contact data, and share these within the PROCEEDR consortium.

Your responses and contact details will be collected and handled in accordance with the PROCEEDR privacy notice which can be found in the Annex.

PROCEEDR aims to use your data responsibly and in line with GDPR requirements.

1. **We need to collect your survey responses and contact details, and share these with the PROCEEDR consortium partners for our research. Please provide your consent for both of these if you wish to continue with the survey. ***

- [ ] I consent to my survey responses and contact details being collected as required for the project
- [ ] I consent to my survey responses and contact details being shared with the PROCEEDR consortium members

Contact details

Your details will be treated confidentially within the consortium in accordance with our Privacy Notice, and we will not contact you further unless you give your consent (there will be an opportunity for this at the end of the survey)

Please provide us with your contact details below: *

Full name:

Your or

Your role/position:

Country:

E-mail address:

Telephone number:

Questionnaire for Industry Stakeholders: Manufacturers & Contractors

I. Keyword: GENERAL

In which kind of road equipment are you interested:

- ☐ Safety Barriers
- ☐ Noise Barriers in the road sector
- ☐ Noise Barriers in the railway sector
- ☐ Other road equipments

What is your range of activities:

- ☐ Raw material / component manufacturer
- ☐ Road equipment manufacturer
- ☐ Installer / Contractor
- ☐ Other

In which European regions/markets does your organisation operate?

- ☐ National market

- ☐ Regional European market
- ☐ Europen market
- ☐ Overseas

Please briefly describe your organisation and the main activities carried out in relation to noise and safety barriers

II. Keyword: ROAD CONSTRUCTION ENVIRONMENTAL SUSTAINABILITY
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.)?

- ☐ Yes, If yes, please mention the schemes you are familiar with
- ☐ No

III. Keyword: ROAD EQUIPMENT ENVIRONMENTAL SUSTAINABILITY
Have you considered (if not yet implemented) implementing some kind of **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?

- ☐ Yes, If yes, please mention some examples of schemes used or other standards, guidelines developed by single companies, manufacturer associations
- ☐ No

IV. Keyword: PROCUREMENT

Have you ever been asked to provide **environmental sustainability criteria in bidding processes/evaluation** in the product/service procurement phase?

☐ Yes, If yes, please mention some examples of criteria used in public tenders

☐ No

V. Keyword: PRODUCT TYPES

Reviewing the list below, can you indicate the type of equipment your company produces / installs? Please tick the relevant ones:

Noise barrier types		
☐	SM	Steel supporting structure + Metal panels
☐	SC	Steel support structure + Concrete panels
☐	SW	Steel supporting structure + Wooden panels
☐	ST	Steel supporting structure + Transparent modules
☐	SP	Steel supporting structure with plastic panels
☐	CB	Self-supporting concrete or brick system
☐	GB	Green barriers
☐	EB	Earth barrier (earth berm)
☐	TC	Tunnel-concrete structure
☐	TS	Tunnel-steel structure
Safety barrier types		
☐	SB	Steel safety barriers
☐	WB	Mixed wood steel safety barriers
☐	PB	Precast concrete safety barriers
☐	IB	In situ cast concrete safety barriers
☐	CC	Crash cushions
☐	IB	Integrated noise safety barriers
☐		mention Other road restaint systems

VI. Keyword: IMPROVING SUSTAINABILITY IN RAW MATERIALS USE

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?

- ☐ Yes, If yes, please provide some examples and/or your company's proposals
- ☐ No

VII. Keyword: IMPROVING SUSTAINABILITY IN MANUFACTURING

With reference to the products your company produces / installs, do you see possible actions / measures to improve the environmental performance in the manufacturing phase?

- ☐ Yes, If yes, please provide some examples and/or your company's proposals
- ☐ No

VIII. Keyword: IMPROVING SUSTAINABILITY IN TRANSPORT AND INSTALLATION PHASE

With reference to the products your company produces / installs, do you see measures to improve the environmental sustainability performance in the installation phase?

- ☐ Yes, If yes, please provide some examples and/or your company's proposals about potential best practices with reference to transportation, foundation works, installation activities
- ☐ No

IX. Keyword: IMPROVING SUSTAINABILITY IN MAINTENANCE / DECOMMISSIONING

With reference to the products your company produces / installs, do you foresee actions/measures to improve the environmental sustainability in the maintenance / decommissioning activities?

- ☐ Yes, If yes, please provide some examples and/or your company's proposals about potential best practices with reference to long term durability, minimizing

maintenance activities along the roads, reuse or recycle products at the end of life…

☐ No

I. Keyword: FURTHER TECHNICAL INFORMATION
PROCEEDR project will be investigating available products/solutions in the market to assess their environmental sustainability. 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 identified in question “V. Keyword: Product types”.

Please attach product information sheets or other relevant information in the attachement to this questionnaire.

Further involvement and contact preferences

To develop effective and practical outcomes we will need to work closely with interested European National Road Authorities and industry organisations. We will be aiming to engage organisations like yours to consult on best practice, exchange information, and disseminate outcomes of the project. We would value your contribution - let us know if you would like to be involved. Please indicate the level of involvement you would like to have (select all which apply):

☐ I'd like to receive project updates via email

☐ I'd like to contribute as a corresponding stakeholder

☐ I don’t want to be involved in any of the above

Please address for sending answers and documents: info@erf.be

Thank you in advance for you time!

The PROCEEDR team

ANNEX B - Survey for NRAs

AUSTRIAN INSTITUTE OF TECHNOLOGY

PROCEEDR - Optimising Resource Use for Roadside Infrastructures
Questionnaire for National Road Autorities

November 2021

Dear representative of a National Road Authority,

Roadside infrastructure today comprises many different road equipment which increasing the volume of materials needed for constructing roads. In the last few decades, the number of products used alongside roads has been widely increased and will continue to increase as technology progresses. As a consequence, road infrastructure requires extensive natural resources and is a major generator of the waste material. Without intervention, this is only expected to increase.

Therefore, the national road authorities are leading an initiative to encourage the recycling and reuse of materials, and the use of renewable and biodegradable materials. CEDR (the Conference of European Directors of Roads) has commissioned an international research project PROCEEDR to address the environmental sustainability issues of the roadside infrastructure and the project is funded through CEDR Call 2020 Resource Efficiency and Circular Economy. Among road equipment, noise barriers and safety barriers have been deemed most relevant. Both have been chosen to serve as study objects of this research project to help the national road authorities to reduce their environmental impacts and to contribute to a circular economy.

As part of the project we are carrying out a consultation with different stakeholders. ´Without any doubts, National Road Authorities are the core-stakeholder in this process and we would greatly appreciate your input into our questionnaire.

We kindly ask you to send us your answers **by January 14th, 2022.** The questions below will take around 30 minutes to answer.

More information about the PROCEEDR project can be found in the attachment with a project summary.

With thanks in advance - **The PROCEEDR team**

Address for sending answers and documents:

Prof. Dr.-Ing. Holger Wallbaum, Chalmers University of Technology, SE-412 96 Gothenburg, holger.wallbaum@chalmers.se

Permissions and consent 1

If you take part in this survey we will need to store your responses and your contact details for further communication on this project - please note that you will have the option to select your desired level of involvement, including not being contacted again.

Your responses and contact details will be collected and handled in accordance with the PROCEEDR privacy notice which can be found on the projects website. PROCEEDR aims to use your data responsibly and in line with GDPR requirements.

Your responses and contact details may be shared with other PROCEEDR project consortia partners (Chalmers University of Technology, AIT - Austrian Institute of Technology GmbH, TRL Ltd, ERF - European Union Road Federation) for analysis and potential further consultation. A data handling agreement will be signed between ERF and all consortia partners prior to sharing your data.

If you wish to participate in this survey we require your consent to collect your survey responses and contact data, and share these within the PROCEEDR consortium.

Please let us know if you wish to continue with the survey. *

- [ ] I am happy to continue with the survey
- [ ] I do not wish to continue with the survey (please consider telling us why in the comment box below)

Comments:

Permissions and consent 2

If you wish to participate in this survey we require your consent to collect your survey responses and contact data, and share these within the PROCEEDR consortium.

Your responses and contact details will be collected and handled in accordance with the PROCEEDR privacy notice which can be found in the Annex.

PROCEEDR aims to use your data responsibly and in line with GDPR requirements.

2. **We need to collect your survey responses and contact details, and share these with the PROCEEDR consortium partners for our research. Please provide your consent for both of these if you wish to continue with the survey. ***

- [ ] I consent to my survey responses and contact details being collected as required for the project
- [ ] I consent to my survey responses and contact details being shared with the PROCEEDR consortium members

Contact details

Your details will be treated confidentially within the consortium in accordance with our Privacy Notice, and we will not contact you further unless you give your consent (there will be an opportunity for this at the end of the survey)

Please provide us with your contact details below: *

name:

Your organisation:

Your role/position:

Country:

address:

Telephone number:

Questionnaire for National Road Authorities

II. Keyword: (KEY) PERFORMANCE INDICATORS

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)?

Yes/No

If yes, please specify them according to the different life cycle stages (if applicable) and performance areas (economy, technology, socio-cultural, environmental).

Economic KPIs: Technological KPIs: Socio-cultural KPIs: Environmental KPIs:

Comments:

III. Keyword: LCA/LCCA OR SUSTAINABILITY ASSESSMENT TOOLS

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)?

Yes/No

If yes, please describe these tools, databases and provide a link/documentation of these examples or the scope/vision/thoughts about the tools/databases you are planning to develop.

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?

Please describe the points that you would consider relevant for the development of a new tool.

IV. Keyword: INNOVATIVE ROADSIDE EQUIPMENT

How would you define innovative (sustainable) roadside equipment?

Are you aware of good practices for innovative and sustainable roadside equipment? Please provide a view examples and if possible, with weblinks.

Are you aware of research projects (ongoing or finished) that have dealt with innovative and sustainable roadside equipment? If possible, please provide the weblinks to the respective projects.

Thank you in advance for you time!

The PROCEEDR team

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