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"Top-Down-Bottom-Up" Methodology as a Common Approach to Defining Bespoke Sets of Sustainability Assessment Criteria for the Built Environment

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Abstract: The top-down-bottom-up (TDBU) methodology for defining bespoke sets of sustainability criteria for specific civil engineering project types is introduced and discussed. The need to define sustainability criteria for specific civil engineering project types occurs mainly in one or both of the following cases: (1) when a more comprehensive and indicative assessment of the sustainability of the project type in question is required; and/or (2) there is no readily available bespoke sustainability assessment tool, or set of criteria, for assessing the sustainability of the project type. The construction of roads, buildings, airports, tunnels, dams, flood banks, bridges, water supply, and sewage systems and their supporting systems are considered to be unique civil engineering/infrastructure project types. The normative definition of sustainable civil engineering/infrastructure projects and the framework for assessing its sustainability is defined and provided by the authors. An example of the TDBU methodology being applied to define sustainability criteria for transport noise reducing devices is presented and discussed. The end result of applying the methodology is a systematically researched and industry validated set of criteria that denotes assessing the sustainability of the civil engineering/infrastructure project type. The paper concludes that the top-down-bottom-up will support stakeholders and managers involved in assessing sustainability to consider all major research methods to define general and unique sustainability criteria to assess and so maximize sustainability. **DOI:** **10.1061/(ASCE)ME.1943-5479.0000169.** *© 2014 American Society of Civil Engineers.*

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Introduction: Rationale for a Methodology to Define Bespoke Sustainability Assessment Criteria for the Various Civil Engineering Project Types

As a result of climate change and current agendas such as Agenda 21 run by the United Nations (UN) for sustainability, every engineering discipline and sectors of society have to play a role to achieve the global position of being sustainable (Jarmin 2008). Therefore, it becomes evident that within the sphere of civil engineering projects, regardless of their size, their design, build, operation, maintenance, and removal consider sustainability throughout its whole life cycle equally to be compliant to the said agenda. Indeed, it is foreseeable policies such as sustainable procurement, sustainability monitoring, and sustainability reporting using relevant criteria become increasingly stipulated by clients and key stakeholders (or may become mandatory within the near future) for the respective industries to win work and/or remain competitive.

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This paper presents an overview of the top-down-bottom-up (TDBU) methodology for defining sustainability assessment criteria for specific civil engineering project types. The need to define sustainability criteria for specific civil engineering project types occurs in one or both of the following cases: (1) when a more comprehensive and indicative assessment of the sustainability of the project type in question is required; and/or (2) there is no readily available bespoke sustainability assessment tool, or set of criteria, for assessing the sustainability of the project type in question. Within the context of this paper, civil engineering project types are (but not limited to) the following: construction of roads, buildings, airports, tunnels, dams, flood banks, bridges, water supply, and sewage systems, and the supporting systems for the aforementioned.

Though many of the available sustainability assessment tools are able to highlight key general sustainability issues to consider, and so assess [for example, sustainable project appraisal routine (SPeAR), building research establishment's environmental assessment method (BREEAM), and civil engineering environmental quality assessment and audit scheme (CEEQUAL), to name but a few], many are unable to highlight key project type specific criteria (i.e., unique to the engineering project type in question) in their assessment of sustainability, and are prescriptive in their nature. Furthermore, it is evident that the sustainability issues to assess invariably vary from civil engineering project type to civil engineering project type, and so the notion of a one size fits all generic set of sustainability criteria for all civil engineering projects is an impossibility, which could lead to omitting key civil engineering project type issues to assess for maximizing sustainability. Hence, the need to guide relevant stakeholders to define a pertinent and robust set of criteria in the absence of research informed and industry validated criteria for the sustainability assessment of their particular project type is salient because there is a current lack of support to achieve this end. As such, it is the main aim of the paper to provide a common approach to defining bespoke sets of sustainability criteria for projects.

Methods to Assess Defined Sustainability Criteria: Multicriteria Analysis Approach versus Rating Approach

It is useful to discuss how criteria are generally used and assessed. There are generally two main approaches within the literature for assessing the sustainability of civil engineering projects. The multicriteria analysis (MCA) approach and the rating approach. The rating systems approach, also referred to as rating tools, within the literature [British Research Establishment (BRE) 2006; Inbuilt 2010; Fowler and Rauch 2006; Uher 1999; Fenner and Ryce 2008] typically rate criteria performance on a set scale. They usually have a prescribed set of modelled criteria and the need to collect data to assess each alternative's performance against the predetermined set of criteria. Rating points or a score are awarded by an assessor or examiner, for example, on a 1–10 scale, for criteria fulfilment, and the alternative that scores the highest is considered the best/most sustainable alternative in the view of the assessor(s). Thresholds are normally set for summed scores to denote the projects' overall level of performance against the predetermined set of criteria, typically as pass, good, very good, or excellent, which may be presented as a certificate.

Many of the most popular sustainability assessment tools such as BREEAM, leadership in energy and environmental design (LEED), SPeAR, and CEEQUAL use the rating approach, which is generally favored by industry because of the easy to follow method and transparency in rating criteria. However, the concept of simply rating criteria on a set scale is its biggest strength and weakness because it allows for total compensation in the performance of criteria. As such, a compromised solution is invariably selected. This is against the fundamental principles of sustainability, which generally state an optimal approach to assessing sustainability is to be taken. Furthermore, the notion of an examiner assigning points on the performance of criteria fulfilment can be criticized as being arbitrary and prone to major bias, and so not scientifically robust, which adds to the argument.

A far more rigorous approach to assessing the sustainability of a civil engineering project type would be to take an MCA approach to assessing sustainability, such as that found in tools like sustainable water industry asset resource decisions (SWARD) and sustainability appraisal in infrastructure projects (SUSAIP). Generally, MCA begins with first defining the overall decision goal, i.e., sustainability, and the formulation and structuring of criteria within a framework (by the assessor) that best represents achieving the said decision goal. Later, a multicriteria decision-making (MCDM) tool can be selected [e.g., simple additive weighting method (SAW), simple multiattribute rating technique (SMART), analytical hierarchy process (AHP), preference ranking organization method for enrichment evaluations (PROMETHEE)] to assess the selected multiple sustainability criteria in relation to one another in an unbiased way. Excellent discussions on MCA can be found in Dodgson et al. (2000), Triantaphyllou (2000), and Yoon and Hwang (1995), to name a few. This approach is different from the more popular rating approach in three major ways: (1) the assessor (s) has/have the flexibility to select or define criteria pertinent to their decision context/project type for assessment; (2) through the process of modeling criteria and applying normalization functions, trade-offs in criteria performance can be equitably highlighted and compared by transforming the entries in the decision to be represented on a 0–1 preference scale; and (3) based on the MCDM tool selected, the best noncompensated solution can be ranked or scored for performance with respect to the set of alternatives considered by applying nontrade-off methods. The MCA approach overall allows for context specific issues to be addressed and discussed, which would have been otherwise omitted in generic sustainability assessment tools, and thereby is a more flexible and conducive approach to promoting innovation instead of predefining all parameters and expecting all solutions to fit that model, as in rating tools. Indeed, a more practical move would be to define the essential requirements for a sustainability assessment method and set out the scope that should be addressed in the context of an accepted and transferrable sustainability assessment framework that can be applied to all civil engineering project types.

It would therefore be useful to have available a systematic method for establishing the set of criteria initially required for MCA to guide stakeholders wishing to identify and maximize sustainability issues to consider, and so assess with regards to their civil engineering project type, as there is a current lack of support for practitioners in this area. Within this paper, stakeholders are defined as "Individuals, groups and/or organisations who affect and/or could be affected by an organisation's activities, products or services and associated performance" (BRE 2009). For civil engineering projects, this usually includes the following: consultants (e.g., design engineers, architects, ecologists, researchers, and solicitors/lawyers), project managers, asset managers, local authorities, contractors, manufacturers, suppliers, construction companies, end users/affected public, maintenance companies, and demolition companies, to name a few.

Given the aforementioned information, it is the purpose of this paper to (1) specify the decision goal, i.e., define what a sustainable civil engineering/infrastructure project is to aid criteria selection; (2) define the sustainability framework for structuring criteria and assessing civil engineering projects' sustainability; and (3) provide a research method to define relevant sustainability assessment criteria specific to the project type in question for MCA.

Defining Sustainability and the Sustainability Assessment Framework for Civil Engineering/Infrastructure Projects

It is important to first discuss and define sustainability and the assessment framework for civil engineering/infrastructure projects before developing a tenable approach for defining sustainability criteria. While it may appear rather obvious, a good starting point for measuring the sustainability of civil engineering/infrastructure projects is to first define what it means within its context (Sahely et al. 2005; Levett 1998). Why? For the following reason: "How can we measure sustainability unless we know what we are trying to measure?" Moreover, Singh et al. (2009) and Bell and Morse (2008) articulate more importantly "how do we know when/if we have achieved 'sustainability' if we cannot measure it?" A normative definition of sustainable civil engineering/infrastructure projects therefore needs to be defined first to guide criteria selection and design to provide a common approach toward assessing the sustainability of civil engineering/infrastructure projects. Moreover, based on the definition given for civil engineering projects' sustainability, an appropriate and transferable sustainability framework is also necessary to structure criteria for assessments.

It is remarkable that despite the prevalence and commitment to the topic of sustainability, there is still no uniform agreement on its meaning, let alone a definitive way to measure it (AtKisson and Hatcher 2001; BRE 2006; McCool and Stankey 2004). This is hardly surprising when there are reported to be over 200 definitions of sustainability, with the most popular definition being Brundtland Commission and World Commission of Environmental and Development's (1987). There are many definitions of sustainability [e.g., Lynam and Herdt 1989; Pearce and Turner 1990; Fresco and Kroonenberg 1992; International Union for Conservation of Nature (IUCN) et al. 1991; Brundtland Commission and World Commission of Environmental and Development 1987], but many are vague and provide little detail on what to sustain, to what extent, and on what timescale. A more practical definition of sustainability within the context of civil engineering is clearly required, which clearly describes what to sustain, to what extent, and on what timescale.

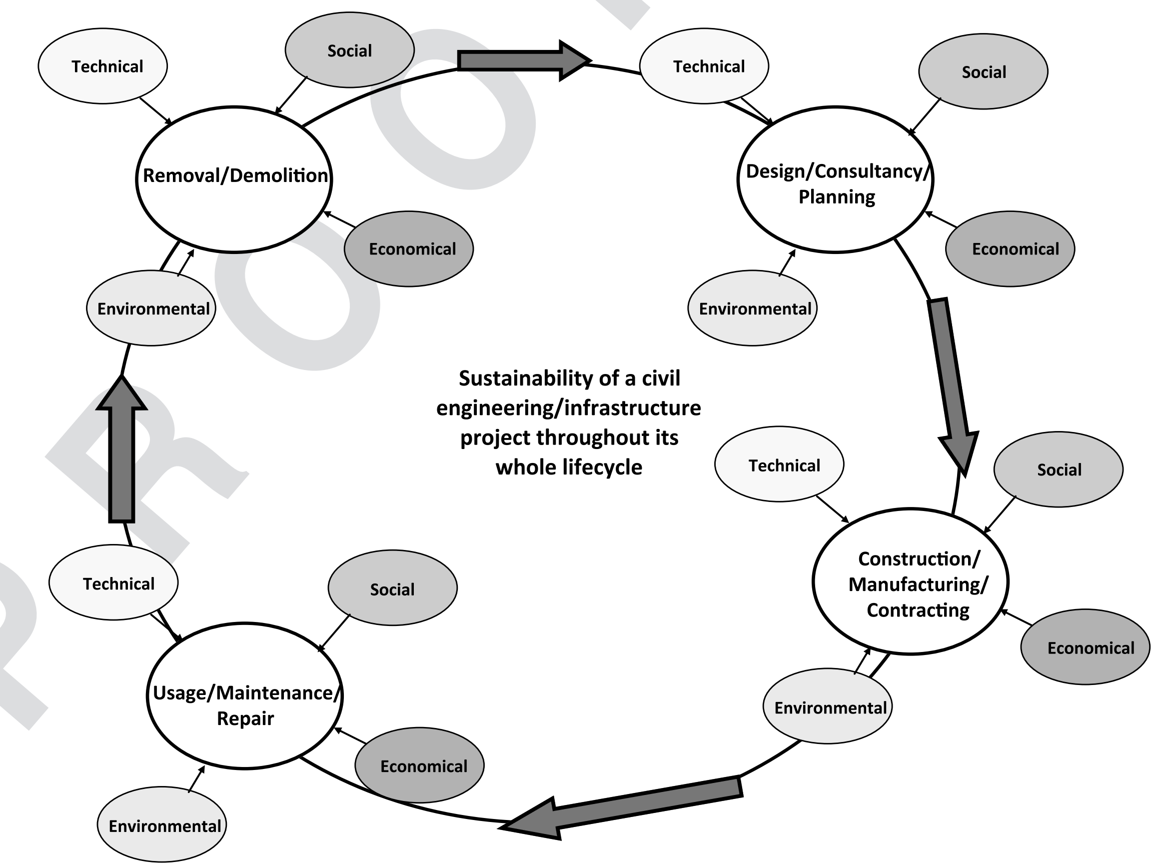
It is often accepted that sustainability encompasses three main components: social, economic, and environment [Olewiler 2008; British Standards Institute (BSI) 2010; Xing et al. 2007; Beloff et al. 2009]. However, for civil engineering/infrastructure projects, a fourth component, technical, is added (and recommended by the authors) to take into consideration the crucial technical performance and functional aspects of engineering projects, while still considering the main three principles of sustainability (Oltean-Dumbrava et al. 2010a, b, c; Ashley et al. 2004). This ensures no trade-offs are made in the technical performance/functional aspect of the civil engineering project in meeting sustainability objectives. Although this addition may be unusual to some academics and practitioners involved in assessing sustainability, it is logical to consider technical sustainability aspects explicitly for what are indeed technical projects. Thus, to provide a practical and contextual definition the relevant stakeholders could utilize, civil engineering projects' sustainability has been broadly defined as the following: "The optimal consideration of technical, environmental, economic and social factors during the design, construction, operation, maintenance and repair, and removal/demolition stages of civil engineering/infrastructure projects" (Oltean-Dumbrava et al. 2010a, b, c).

Fig. 1 illustrates the aforementioned definition by highlighting how the factors of sustainability should be incorporated throughout the whole life cycle of civil engineering/infrastructure projects.

The sustainability definition provides the spatial and temporal context required with clear aims on how to achieve sustainability without specifying specific objectives. A selected life cycle stage could be assessed for sustainability instead of the whole life cycle. Therefore, criteria should be selected or created that denotes assessing sustainability, as shown in Fig. 1.

An assessment framework is required to structure and order criteria sets for assessment. Fig. 2 shows the proposed sustainability framework for assessing the sustainability of civil engineering/infrastructure projects based on the definition given for sustainability.

The framework shown in Fig. 3 simply sets the boundaries for projects' sustainability to be assessed within, which represents the decision goal and provides a means to structure and order (through a nested hierarchical system) criteria and indicators (Oltean-Dumbrava et al. 2010a). Sustainability factors (sometimes refered to in the literarature as principles/dimensions/aspects/considerations) are fixed aspects for sustainability, and allow for the arrangement of relevant criteria and indicators through the sustainability framework. Primary criteria are key general themes that characterize assessing the sustainability factor under consideration for the civil engineering/infrastructure project type in question. Primary criteria are not usually measurable, and will typically have a set of secondary criteria below them that define the primary criteria. Secondary criteria underpin the primary criteria and are specific to the primary criteria under consideration. They are measured through the use of indicators, which are the unit of measurement



F1:1 **Fig. 1.** Sustainability factors to be considered throughout the whole life cycle of civil engineering/infrastructure projects

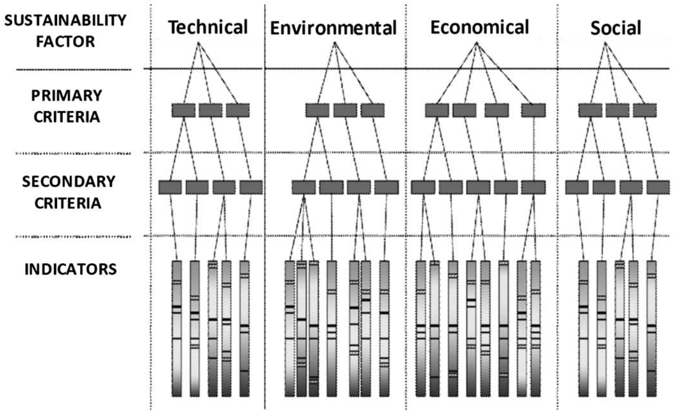


Fig. 2. Sustainability framework for assessing the sustainability of civil engineering/infrastructure projects

for secondary criteria, and are either quantitative or qualitative. Furthermore, in some cases, secondary criteria may have further attributes/tertiary criteria that define them further and are measured through the use of indicators as well. This hierarchy of criteria levels and the aggregation of criteria values can continue ad infinitum; however, typically more than three levels are not seen within the literature (e.g., SWARD and BREEAM).

Given the aforementioned points raised within this section, the authors are confident that the definition of sustainable civil engineering projects, and the sustainability framework provided, is sufficiently transferrable to denote commonly assessing the sustainability of most civil engineering project types, such as the construction and management of roads, buildings, airports, tunnels, dams, bridges, water supply, and sewage systems, and the supporting systems for the aforementioned. The ensuing top-down-bottom-up methodology places emphasis on investigating what sustainability criteria and indicators could be selected or created to assess each major factor of sustainability at each life cycle stage of the civil engineering/infrastructure project type under investigation.

Top-Down-Bottom-Up Methodology for Defining Relevant Sustainability Assessment Criteria for Unique Civil Engineering Project Types

There is a dearth of literature for the actual development of a bespoke sustainability assessment method (i.e., tool) from its inception for civil engineering projects, which includes (1) defining the sustainability framework; and (2) defining the relevant sustainability assessment criteria for the project type in question. The need to define a logical and robust method for defining sustainability criteria for unique civil engineering projects is evident where hitherto their sustainability has not been widely considered (for example, roadside transport noise barriers, flood alleviation schemes, or construction products). Upon consulting the following key literature, BSI (2010), Sanchez and Lopez (2010), Lundin (2003),

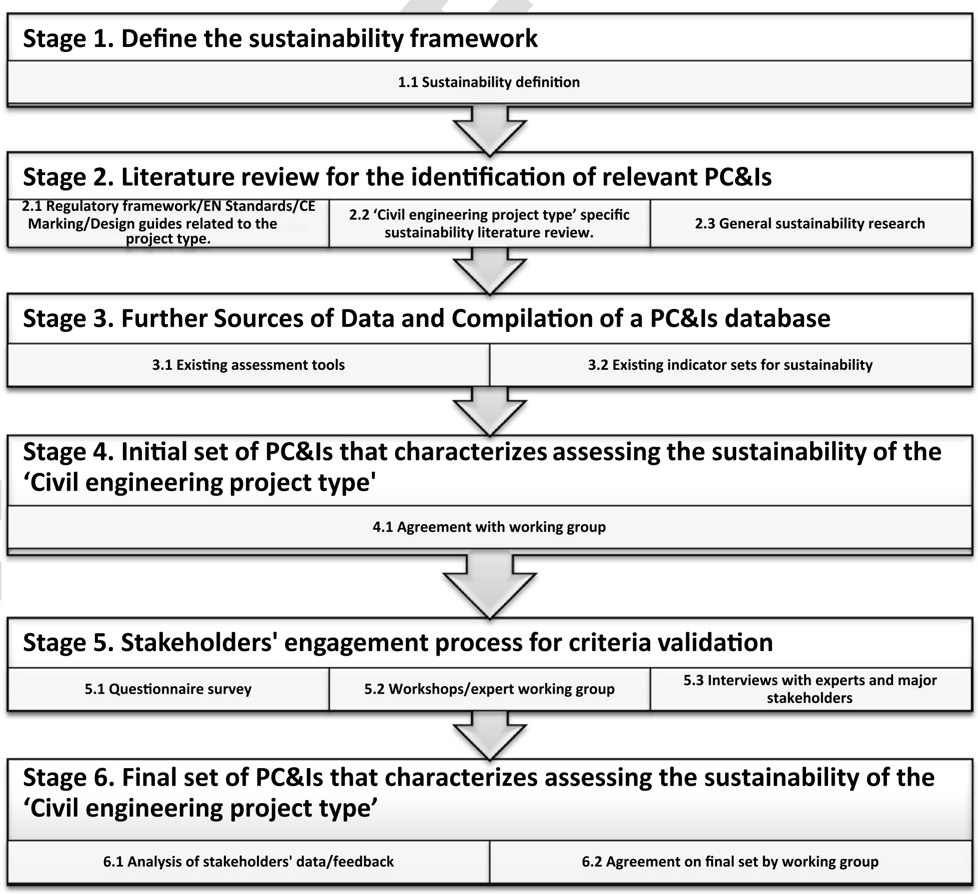


Fig. 3. Top-down-bottom-up research strategy for defining the relevant generic sustainability criteria and indicators that characterize assessing the whole life sustainability of specific civil engineering/infrastructure project types (PC&I = potential criteria and indicators) [adapted source: Oltean-Dumbrava et al. (2010a)]

AtKisson et al. (2004), Dasgupta and Tam (2005), Segnestam et al. (2000), Ugwu and Haupt (2005), Office of Deputy Prime Minister (ODPM) 2005, Bell and Morse (2008), and Fortunet and Quevedo (2005), the authors subsequently synthesized the discrete methods utilized by the aforementioned for developing frameworks, criteria, and indicators, and developed the top-down-bottom-up research strategy for defining the relevant set of sustainability assessment criteria for unique civil engineering project types, presented in Fig. 3.

The purpose of the top-down-bottom-up research methodology is to consider all major possible research methods and sources of data to identify relevant criteria that denote assessing the sustainability of the civil engineering project type in question. All identified relevant criteria are added to a user created database of potential criteria and indicators (PC&I), and are screened later on for relevance and structured into an appropriate hierarchy. An overview of the top-down' and bottom-up aspect of the methodology is given herein for the readers' information.

Two distinctive approaches are recognizable within the literature for developing a sustainability framework and designing/validating sustainability criteria and indicators. This has been broadly classified by Lundin (2003) as

1. The top-down approach: Experts and/or the working group define the framework and the set of sustainability criteria.
2. The bottom-up approach: Participation of different stakeholders in the design of the framework and the sustainability criteria selection process.

For instances of both approaches being primarily taken discretely, see AtKisson et al. (2004) for taking a bottom-up approach through the indicators, systems, innovation, strategies (ISIS) method for assessing regional sustainability, and Dasgupta and Tam (2005), in their development of the technical sustainability index (TSI), take a top-down approach for assessing infrastructure projects.

However, both methods used in isolation have their pros and cons. The top-down approach runs the risk of taking a narrow view and missing out on PC&I crucial to defining and assessing the sustainability of the civil engineering project type, which can only be identifiable by relevant stakeholders through consultation and validating the developed model. Conversely, the bottom-up approach runs the risk of taking up a lot of time, creating a complex model, and missing out on key PC&I, which may only be identifiable by experts in the field of sustainability and through academic research.

The need to consider both approaches to avoid the pitfalls of using only one method is most judicious. Therefore, both approaches should be implemented for achieving two distinct purposes:

1. Top-down methodology: To define sustainability, the assessment framework, and the initial potential set of primary criteria and indicators that characterize assessing the sustainability of the civil engineering project type in question by experts; and
2. Bottom-up methodology: For stakeholders to validate the proposed set of sustainability (namely the technical, environmental, social, and economic) criteria that epitomizes assessing the sustainability of the project type in question. Here, the stakeholders are to be asked whether any criteria proposed should be added or removed from the set, and to rank/rate each criterion in terms of importance. This is achieved through a stakeholders' engagement process, involving a combination of either workshops, interviews with experts and key players, and/or questionnaire surveys to target as many stakeholders as possible involved throughout the whole life of the civil engineering project type in question.

The amalgamation of both methods have been shown in Fig. 3, whereby stages 1–4 highlight taking a top-down approach to define the sustainability framework and the initial hierarchy of criteria and indicators that characterize assessing the sustainability of the civil engineering project type in question, and stage 5 highlights taking a bottom-up approach to target stakeholders involved throughout the whole life of the civil engineering project type in question to validate and add/remove criteria. Pursuant to the TDBU methodology, stage 6 assesses the stakeholders' feedback and affirms the final set of sustainability criteria for the project type under investigation.

Detailed Overview of the Top-Down-Bottom-Up Methodology

With reference to Fig. 3, a succinct overview of the methodology, process, and the rationale behind each major stage is described subsequently.

Stage 1. Define the Sustainability Framework

- Stage 1.1 Sustainability definition: This is the first and most important task to define the framework in which criteria and indicators can be arranged and so assessed within. At this point, it is recommended that the fixed definition of sustainable civil engineering projects and the sustainability framework postulated by the authors be used to aid defining criteria.

Stage 2. Literature Review for the Identification of Relevant Potential Criteria and Indicators

The key purpose of this stage is to identify issues unique to assessing the sustainability of the civil engineering project type in question while still reviewing general issues for sustainability in civil engineering projects. This can be achieved in three steps, which are elaborated subsequently as

- Stage 2.1. Regulatory framework/EN standards/CE marking/design guide: Typically, a number of well researched and industry consulted standards, design guides, and regulatory frameworks exist for the specific civil engineering project type in question. A review of technical/legislative information related to the civil engineering project type should be completed for identifying aspects of sustainability (namely technical, environmental, social, and economic) that may be already incorporated/achieved within them. This could help bring to the fore PC&Is that could characterize assessing the sustainability of the civil engineering project type in question. The results of this stage should be added to the PC&Is database for screening and analysis later on.
- Stage 2.2. Civil engineering project type specific sustainability literature review: Of published scientific and research literature on the sustainability of the specific civil engineering project type in question (where possible) and/or review of literature on the economic, environmental, social, and technical impacts of the civil engineering project type to gain a deeper understanding of the major technical, economic, environmental, and social impacts of the specific civil engineering project type across its whole life, and so create unique PC&Is to reflect assessing the aforementioned four factors of sustainability. Where appropriate, the results of this stage are to be added to the PC&Is database for screening and analysis later on.
- Stage 2.3. General sustainability research: Published in peer reviewed journals, review of how sustainability (or the individual factors of sustainability) in other construction projects within a similar spatial context has been addressed in the interest of gaining further potential PC&Is that could be transferable to encapsulate assessing the sustainability of the project type in

question. The findings of this stage are also be added to the PC&Is database for filtering/analysis later on.

Stage 3. Further Sources of Data and the Compilation of a PC&Is Database
The aim of this stage within the research strategy is to formally conclude compiling the PC&Is database, which denotes assessing the environmental, economic, technical, and social aspects of the civil engineering/infrastructure project type in question. Once completed, it will be possible to select relevant primary criteria, secondary criteria, and indicators from the PC&Is database, and structure sets for assessing each factor of sustainability for the project type in question. Stage 2 is also expanded further by considering the two subsequent key sources for identifying further PC&I because of them being either supported by their respective industry, developed through research, and/or for their prevalent use of being practically applied.

- Stage 3.1. Existing assessment tools: Currently used for assessing sustainability or aspects of sustainability (i.e., social, economic, environmental, and technical) to identify further potential PC&Is that could be transferable or adapted to suit the context of the civil engineering project type in question. Normally, these tools are widely used by their respective industry and supported by research. As such, the various PC&Is that could be identified here are usually more than validated. The findings of this stage are to be also added to the PC&Is database for filtering/analysis later on.
- Stage 3.2. Existing indicator sets for sustainability: There already exist databases, or sets of indicators/criteria for sustainability, from which one can select the most apt to fit their context and project type, for example, the United Kingdom, Quality of Life Counts; the construction and city related sustainability indicators (CRISP) database; and the sustainable building alliance (SBA) database. Where appropriate, the results of this stage are to be added to the PC&Is database for filtering/analysis later on.

Stage 4. Initial Set of PC&Is that Characterize Assessing the Sustainability of the Civil Engineering Project Type

- Stage 4.1. Agreement with working group: From selecting criteria from the compiled database of PC&I, the working group (i.e., the team of experts or DMs involved with the project in question) are to structure a tentative hierarchical set of relevant generic sustainability assessment criteria that denote assessing the sustainability of the civil engineering project type under scrutiny. The initial set of criteria should embody assessing/optimizing the economic, technical, environmental, and social aspects of the civil engineering project type under investigation. Criteria here should be selected primarily on the basis of relevance, understandability, and data availability. The initial set of criteria should be agreed with the working group before being put through the stakeholders' engagement process for criteria validation and refinement.

Stage 5. Stakeholders' Engagement Process
The principal purpose of this stage is to validate the initial proposed set of PC&Is with all relevant stakeholders (see definition) involved throughout the whole life of the civil engineering project type in question. Therefore, this stage invites all stakeholders to participate by commenting on if any criteria should be added or removed from the initial proposed set of criteria through either of the following:

- Stage 5.1. Questionnaire survey: Sent out to all stakeholders involved throughout the whole life of the project to comment and validate the initial set of sustainability assessment criteria for the civil engineering project type by either rating or ranking the proposed set of criteria.
- Stage 5.2. Workshops: To bring together all relevant stakeholders to gauge further opinions on the proposed set of sustainability assessment criteria for the sustainability assessment of the civil engineering project type.
- Stage 5.3. Interviews with experts and major stakeholders: To gain an even deeper understanding of key sustainability issues that may need to be considered throughout the whole life of the civil engineering project type, and validate the proposed set of criteria and/or indicators.

Stage 6. Final Set of PC&Is that Characterizes Assessing the Sustainability of the Civil Engineering Project Type
This stage confirms the final hierarchical set of sustainability assessment criteria and indicators following garnering and analyzing feedback from the relevant stakeholders, which will characterize assessing the sustainability of the civil engineering project type in question. The final set of PC&Is that denotes assessing the sustainability of the civil engineering project under study is affirmed through completing two main steps, listed as follows:

- Stage 6.1. Analysis of stakeholders' data: From the stakeholders' engagement process, to remove, add, and validate the most suitable criteria and indicators through quantitative and qualitative analysis of the questionnaire surveys, workshops, and interviews with experts and major stakeholders.
- Stage 6.2. Agreement on final sustainability criteria set by working group: The expert working group on the sustainability of the civil engineering project type will/should validate the final set of PC&Is. Thus, one is left with a systematically researched and industry validated set of sustainability assessment criteria that denotes assessing the sustainability of the civil engineering project type. This will provide the basis for conducting a MCA for assessing and/or reporting on sustainability.

A case study example of implementing the TDBU method for defining the set of relevant generic sustainability assessment criteria for a unique civil engineering project type is given herein.

Case Study: Defining the Relevant Generic Set of Sustainability Assessment Criteria for Noise Reducing Devices Projects for EU Project QUIESST

Transport noise reducing devices (NRD) projects are unique civil engineering projects. Noise reducing devices such as noise barriers, absorptive claddings, and road covers form a major a part of the European transport infrastructure and are designed to control the spread of surface road and railway noise to impacted communities. However, a relevant generic set of sustainability assessment criteria and an associated method for assessing their whole life sustainability does not exist for the NRD industry. Quietening the environment for a sustainable surface transport (QUIESST) (2010) European Union (EU) grant is a three-year, inter and multidisciplinary project undertaken by 13 EU partners from eight countries, which began in late 2009. Work package 6 (WP6) and its specialist research team are researching the sustainability of NRDs across their whole life cycle.

The main aim of WP6 is to provide a bespoke sustainability assessment framework and method for assessing the whole life sustainability of NRDs, which will form part of the guidebook to NRD optimization in a sustainable way aiming to be the future reference source for noise mitigation by NRDs. This tool will assist the relevant stakeholders (e.g., decision makers, transport engineers, urban/transport planners, and other relevant stakeholders involved with NRDs) to assess the sustainability of each major life cycle stage and so make more sustainable decisions. As there was no readily available bespoke sustainability assessment tool, or set of

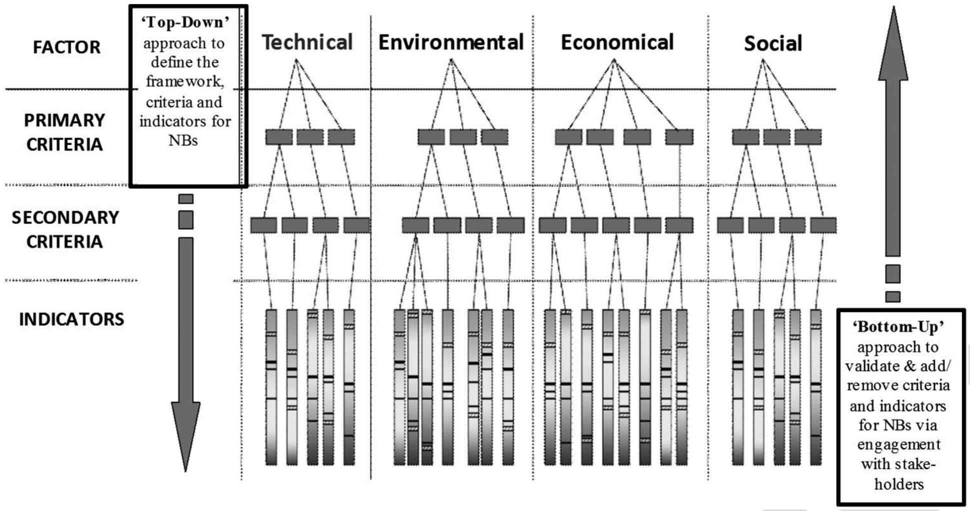


Fig. 4. Top-down-bottom-up approach for defining the relevant generic sustainability assessment criteria and indicators for NRD projects (NB = noise barriers that are classified under NRDs) [source: Oltean-Dumbrava et al. (2010b)]

criteria, for assessing the sustainability of NRD projects, the TDBU methodology for creating and defining sustainability assessment criteria for unique civil engineering/infrastructure project types was selected and implemented to define the relevant generic set of sustainability criteria necessary for assessing the sustainability of NRD projects through a MCA approach, presented and discussed herein as a case study example.

Method: TDBU Methodology for Defining and Validating Sustainability Criteria for Unique Civil Engineering Projects

Fig. 4 illustrates the implementation of the top-down-bottom-up methodology within the context of the sustainability framework for defining and validating the set of sustainability assessment criteria for NRD projects.

The top-down approach involved the dedicated cohort concerned with NRDs' sustainability researching and generating the initial set of criteria for validation, whereas the bottom-up aspect involved a stakeholder's engagement process to validate, add, remove, and comment on the proposed set of criteria by means of

- A survey of key stakeholders involved in the NRD industry across Europe;
- Group workshops of key stakeholders involved throughout the whole life of NRDs; and
- Interviews with key stakeholders and experts.

Primarily a questionnaire-based survey was developed containing the proposed set of generic sustainability criteria, whereby the responders were asked to rate, rank, add, and remove criteria, and validate/comment on the generic set of sustainability criteria for NRDs projects. The questionnaire consisted of two major parts:

1. The first part addresses one of the four sustainability factors, e.g., economic/cost considerations, and asks the respondent to rank the related primary criteria in terms of their importance that define it, e.g., life cycle cost, effect on local residential/commercial property prices, contractual and procurement type, and so on. The respondent is also given the choice to add/remove primary criteria.
2. The second part asks the respondent to rate on a 5-point Likert scale how important they consider each primary/secondary/tertiary criterion (i.e., 1 = very important, 2 = important, 3 = moderately important, 4 = of little importance, 5 = unimportant). An option is also provided to add any further primary/tertiary/secondary criteria they consider important for assessing the sustainability of noise barrier projects.

Note that adopting the Likert scale for validating sustainability criteria is a typical method utilized by other sustainability assessment tool developers (e.g., Ugwu et al. 2006) because it allows one to perform meaningful and transparent statistical analyses for determining the relative importance of criteria by the stakeholders. The results will be presented in a table showing their individual ranking overall and within their respective sustainability factor.

Results from Questionnaire Survey

The NRDs' sustainability criteria validation questionnaire-based survey was conducted over a 5-week period from October 4, 2010 through November 5, 2010. The QUIESST (2010) consortium and their available network(s) were fully utilized to gain meaningful responses from a wide range of organizations/individuals that include national road and rail authorities, planning authorities, contractors, manufacturers, consultants, designers, acoustical engineers, asset managers, and researchers across Europe. A total of 31 questionnaires were returned, which given the small niche market size of NRDs, the general historic reluctance of stakeholders to participate, and the wide range of stakeholders represented, was considered a good sample size to perform meaningful statistical analysis. However, it should be noted that it proved to be difficult to receive all questionnaires fully completed, and as such, the results of the most relevant questions are given. This covers the ranking and rating of the primary criteria. The calculation of Kendall's coefficient of concordance for the ranking data and the 2-way analysis of variance (ANOVA) for the rating data for each criterion with their standard deviation were primarily used to analyze the data collected in determining the stakeholders' agreement for the said criteria. Fig. 5 gives the breakdown of these respondents by work sector.

A problem to overcome was missing data, e.g., there was no reply, a "do not know" category was ticked, or an invalid reply was given. For the statistical analysis of data, it was important to include only those complete sets of rankings/ratings. For this reason, although 31 questionnaires were received, it was not possible to include all replies. In the tables, the numbers of valid replies are given.

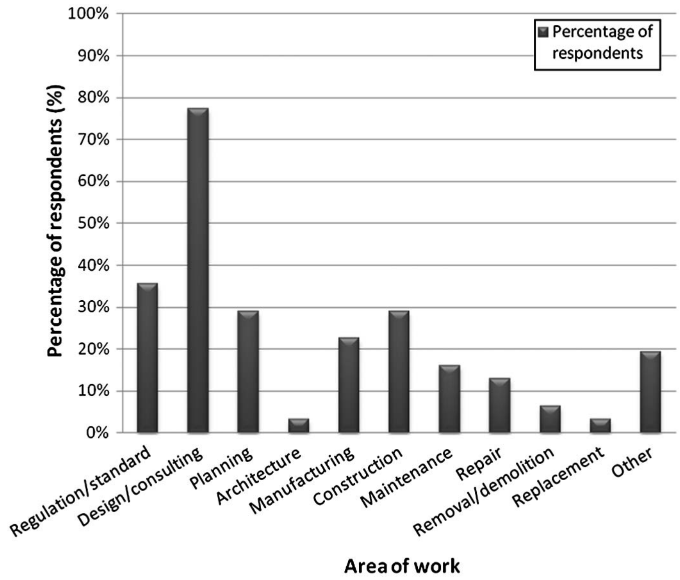


Fig. 5. Respondents' specialist area of work within the NRD industry

Sustainability Factors

A general question was included to determine which sustainability factors the respondents felt were the most important to consider throughout the whole life of NRDs. Respondents were asked to rank the four sustainability factors (outlined in Fig. 1) in the order of importance with rank position one denoting the most important to consider and last place (4th) denoting the least important. Table 1 shows the mean rank (i.e., summing the ranks obtained from all respondents and then taking these sums to obtain an overall ranking average) for each sustainability factor based on the questionnaire results. For this question, all respondents gave valid responses.

The results show that the majority of the respondents ranked the technical/acoustical performance factor as the most important to consider throughout the whole life of NRDs. This is an understandable result because in many cases, it is essential that public expenditure of achieving a desired noise reduction through a mitigation measure be justified to stakeholders. The environmental impact of the project ranked, on average, as the second most important factor, with economic/cost criteria and social criteria being ranked close to third on average. The similar rankings given to economic and social factors agree with previous research findings (Joynt and Kang 2006). The results of the calculation of the Kendall coefficient of concordance W (a statistic indicating the degree of agreement between respondents) show that when $k = 31$ respondents and the number of ranked items is $N = 4$ (sustainability factors), their agreement was $W = 0.47$. A value of W of 1 represents total agreement, and 0 represents no agreement at all. The level of significance is $p = 0.01$ (1%). Therefore, the authors reject the null hypothesis that the respondents' ($k = 31$) rankings are unrelated to one another. The significant correlation indicates a reasonable degree of agreement among respondents (Siegel and Castellan 1988).

Table 1. Average Ranking of Sustainability Factors

Sustainability factor	Average ranking position (out of 4)
Acoustic/technical performance	1.10
Environmental impacts	2.39
Economic/cost considerations	2.84
Social considerations	3.03
Kendall's W	0.47
Test for significance	Significant at the 0.01 level

Note: Sample size is 31.

Social Criteria

The next part of the questionnaire focused on validating the proposed set of social criteria for considering and assessing the social factor in the sustainability assessment of NRD projects, which was split into two parts to generate ranking data and rating data for analysis. Respondents were asked to rank primary criteria, i.e., key general issues that define the social factor in the order of their importance, in which 1st place is most important. Subsequently, respondents were then asked to rate individually all primary, secondary, tertiary, and quaternary social criteria on the Likert scale of 1–5. For each type of question, respondents were given the option to state "do not know" and provide further not listed criteria they consider important for assessing the sustainability of NRDs. As noted previously, only the analysis of the primary criteria are reported here.

Stakeholders were asked to rank, based on their opinion, seven primary social criteria in the order of importance to characterize assessing the social factor for NRD projects. Based on 11 valid replies, Table 2 shows the mean rank for each primary social criterion

In evaluating the results highlighted in Table 2, it is clear to see that safety and security and health and well-being were considered most important above all other social primary criteria by the stakeholders. This is not wholly surprising because the issue of considering health and safety is already (within the developed countries) well embedded in construction practices and related legislation, acts, and so on. Severance that results from the blocking, or partial blocking, of vehicular and pedestrian access by the NRD was felt by the respondent as the third most important factor to consider. This issue is likely to play a large role in determining overall social acceptance. This result was also expected because this factor is becoming widely recognized as important for the whole success of the NRD scheme. Local employment, community engagement, and design were ranked lowest. It is likely that severance, community engagement, and design were partly taken into account in the relatively high rating given to social acceptance. Furthermore, the results of the Kendall coefficient of concordance show that when $k = 11$ and respondents rank $N = 7$ primary social criteria, their agreement was $W = 0.5$ ($p < 0.01$, i.e., statistically significant at the 1% level). Again, there is a reasonable measure of agreement between respondents.

Table 3 ranks the mean rating received for the primary social criteria only. It should be noted that 37% of the ratings were missing (because of respondents either not fully completing the questionnaire and/or opting to tick "do not know" for rating criteria), so the results should be used with caution.

Table 2. Average Rank for Primary Social Criteria

Social criteria	Average ranked position (out of 7)
Safety and security	2.00
Health and well-being	2.27
Severance	3.73
Social acceptance	4.09
Architectural design and local context	4.36
Community engagement	5.27
Local employment and engagement with local business	6.27
Kendall's W	0.50
Test for significance	Significant at the 0.01 level

Note: Sample size is 11.

Table 3. Average Rating for the Primary Social Criteria

Rank	Primary social criteria	Average	Sample size	SD
1	Health and well-being	1.28	18	0.46
2	Safety and security	1.53	19	0.70
4	Social acceptance	2.59	17	1.12
3	Architectural design and local context	2.70	20	1.22
5	Community engagement	2.89	18	1.23
7	Severance	3.57	14	1.28
6	Local employment and engagement with local businesses	3.64	14	1.60

The average ratings presented in Table 3, although incomplete, correlate with the mean rankings ($r = 0.82$, $p < 0.05$). It is clear that issues relating to health and safety and safety and security are considered important to very important by the stakeholders, whereas all subsequent primary criteria are considered important to moderately important. Safety being rated by the respondents as a very important criterion is an understandable result. In particular, because of the presence of an active claims culture, the notion of safety first is a particularly salient issue that can cost organizations tens of thousands or even millions, if precautions are not fully taken into account. However, a few respondents commented that they felt community engagement and social acceptance should be made a mandatory requirement for NRD projects, and is the most important barometer to determine the social success of a project.

Economic Criteria

Stakeholders were asked to rank six primary economic/cost criteria in the order of importance to characterize assessing the economic/cost factor for noise barrier projects. Based on eight complete sets of rankings, Table 4 shows the mean rank for each primary economic/cost criterion.

It is clear to see that life cycle cost was considered, by a large margin, as the most important above all other economic/cost primary criteria by the stakeholders. Also, it is noted that the effect on local property prices and the contractual and procurement type was ranked the lowest by the respondents. Furthermore, the results of the Kendall coefficient of concordance show that when $k = 8$ respondents rank $N = 6$ primary economic/cost criteria, their agreement was $W = 0.41$ ($p < 0.01$).

Table 5 ranks the mean rating received for these primary economic/cost criteria.

The results presented in Table 5 agree well with the ranking data. The correlation between the two sets of data is close with $r = 0.93$ significant at $p < 0.01$. It is clear that issues relating to life cycle cost are considered very important by the stakeholders, whereas all subsequent primary criteria are considered important to moderately important. However, overall it would appear that life cycle cost is the most important economic consideration and may be enough to consider as the only economic criterion necessary to assess the economic factor. This will be considered further in the next stage of the project.

Table 4. Average Rank for Each Primary Economic/Cost Criterion

Primary economic criteria	Average ranked position (out of 6)
Life cycle cost	1.38
Green value	3.19
Financial sources	3.63
Compensation cost	3.69
Effect on local residential/commercial property prices	4.56
Contractual and procurement type	4.56
Kendall's W	0.41
Test for significance	Significant at the 0.01 level

Note: Sample size is 8.

Technical Criteria

Stakeholders were asked to rank three primary technical criteria in the order of importance. Table 6 shows the mean rank for each primary technical criterion based on 27 complete sets of rankings.

From Table 6, it is evident that material selection and buildability/constructability were considered more important than the flexibility and adaptability. The results for the Kendall coefficient of concordance show that when $k = 27$ respondents rank $N = 3$ primary technical criteria, their agreement was $W = 0.23$, which is statistically significant ($p < 0.01$).

Table 7 ranks the average ratings received for the primary technical criteria.

The results presented in Table 8 agree well with the ranking data in which the correlation coefficient was very high with $r = 0.998$ ($p < 0.01$). The average ratings fell in a fairly narrow range, and overall, it appears that the majority of the respondents felt all of the primary technical criteria proposed were important and relevant to assessing the technical sustainability of NRD projects.

Environmental Criteria

Table 8 shows the mean rank for each primary environmental criterion.

The results in Table 8 show great ambivalence among the stakeholder for ranking all primary environmental criteria. It becomes apparent that there is no large difference between the environmental criteria. This is supported by the results of the Kendall coefficient of

Table 5. Average Rating for the Primary Economic/Cost Criteria

Rank	Primary economic criteria	Average	Sample size	SD
1	Life cycle cost	1.28	18	0.46
2	Compensation cost	2.39	18	1.14
3	Financial sources	2.67	15	1.23
4	Green value	2.89	18	1.08
5	Contractual and procurement type	3.07	15	1.10
6	Effect on local residential/commercial property prices	3.24	25	1.05

Table 6. Average Rank for Primary Technical Criterion

Primary technical criteria	Average ranked position (out of 3)
Material selection	1.54
Buildability/constructability	2.06
Flexibility and adaptability	2.41
Kendall's W	0.23
Test for significance	Significant at the 0.01 level

Note: Sample size is 27.

Table 7. Average Rating for Technical Criteria

Rank	Criteria level	Primary technical criteria	Average	Sample size	SD
1	1	Material selection	1.30	20	0.47
2	1	Buildability/constructability	1.85	26	0.83
3	1	Flexibility and adaptability	2.14	22	0.89

Table 8. Average Ranking for Primary Environmental Criteria

Primary criteria	Average ranked position (out of 6)
Energy	2.74
Land use	3.26
Air quality and climate change	3.35
Flora and fauna	3.74
Water	3.74
Waste	4.18
Kendall's W	0.08
Test for significance	Not significant

Note: Sample size is 17.

Table 9. Average Rating for Environmental Criteria

Rank	Primary environmental criteria	Average	Sample size	SD
1	Flora and fauna	1.95	19	1.08
2	Land use	2.25	18	1.11
3	Energy	2.32	19	1.29
4	Air quality and climate change	2.32	19	1.29
5	Waste	2.81	21	1.25
6	Water	2.88	17	1.45

concordance, which show that when $k = 17$ respondents rank $N = 6$ primary environment criteria, their agreement was very low with $W = 0.08$ and failed to reach the level of significance even at the $p < 0.05$ level.

The ratings of the primary environmental criteria are shown in Table 9.

Not surprisingly, there is no agreement between the rankings and the ratings presented in Table 9 ($r = 0.41$, which is not statistically significant). The small range in the ranking and ratings indicates the difficulty of separating these environmental criteria.

Case Study Discussion

To achieve a viable and practical framework for procuring sustainable NRDs, it is necessary to identify a list of sustainability criteria and indicators specific to NRDs and indicate their relative importance. Unfortunately, whole life cycle design of NRDs are currently not in line with the growing sustainability agenda for a sustainable surface transport, such as not fully taking into account the whole life cycle cost, calculating the carbon footprint of projects, ensuring future proof designs for the possible impact of climate change, and creating designs sympathetic to the impacted communities (Oltean-Dumbrava et al. 2012). This underlines the need to define relevant generic sustainability criteria for comparing technical, social, environmental, and economic factors for different NRD types at a specific site.

The top-down-bottom-up methodology was implemented to define the relevant generic set of sustainability assessment criteria and assessment framework for NRD projects. A set of systematically researched and industry validated generic set of sustainability assessment criteria that denotes assessing/optimizing the technical, environmental, social, and economical factors of NRD projects is now available to all relevant stakeholders to utilize as a result of the research carried out. It is now possible to select appropriate criteria for carrying out a MCA to determine the whole life sustainability of NRDs projects. A number of 22 primary criteria together with secondary criteria and indicators were identified, shown in Table 10. In total, 126 individual sustainability criteria make up

Table 10. Primary Criteria for Assessing the Sustainability of Noise Barrier Projects

Sustainability factor	Primary criteria
Technical	Material selection
	Ease of building/construction
	Flexibility and adaptability
Economic	Life cycle cost
	Green value
	Financial sources
	Compensation cost
	Effect on local residential/commercial property prices
	Contractual and procurement type
Social	Safety and security
	Health and well-being
	Severance/separation
	Social acceptance
	Architectural design and local context
	Community engagement
	Local employment and engagement with local business
Environmental	Energy
	Land use
	Air quality and climate change
	Flora and fauna
	Water
	Waste

the generic set of pertinent criteria affirmed for NRD projects. The factors are placed in order of mean rank (see Table 1), and within each factor, the primary criteria are in turn also ranked based on the results in Tables 2, 4, 6, and 8. This provides a convenient summary of the relative importance of four factors and 22 primary criteria.

Within the context of NRD projects, noise is considered as a technical-acoustical design consideration, and so to avoid double counting, has been omitted from being included within the environmental factor. Table 11 highlights a few example bespoke/unique criteria specific to NRD projects for each sustainability factor, as a result of implementing the TDBU methodology.

However, one should be mindful that the final presented list of 22 primary criteria—and the numerous secondary and tertiary criteria related to it for NRD projects—is not definitive; it is a modifiable set of criteria. If required, users can develop and add further primary and secondary criteria they feel are appropriate based on the strategy discussed within this paper. Indeed, it would be unknowledgeable to assume that the generic set of sustainability criteria defined for NRDs (or for any other civil engineering project type) is definitive. The generic set of sustainability criteria defined now represents the current state-of-the-art thinking in sustainability, issues related to NRDs, and the demands of the current political environment. However, as the knowledge and practice of the aforementioned change over time, so will the issues that are considered important change for the end user or project. Thus, it is important that the generic set of sustainability criteria defined for NRDs (or for any particular project type) evolve over time and be subject to revisions and refinement. Because of implementing the TDBU methodology, the authors believe all the major issues/primary criteria listed for each sustainability factor characterizes the main issues that should be considered for assessing the sustainability of NRD projects across their whole life. As such, the authors do not foresee any likely additions to the list of primary criteria, but a large scope to add/develop numerous further secondary and tertiary criteria for each primary criterion as deemed fit.

Table 11. Example Unique Criteria Defined for Assessing the Sustainability of Noise Barrier Projects as a Result of Implementing the TDBU Method

Sustainability factor	Sustainability criteria unique to NRD projects
Technical	Ability of the NRD to change as required (for example, to increase the height of the noise barrier should there be an increase in noise emissions)
	Acoustic durability
	Resistance of the NRD system to the potential impacts of climate change
Economic	Income generation because of the noise barrier (i.e., from the use of advertising or solar panels on the face of the barrier)
	Effect on local residential/commercial property prices because of the placement of the NRD
Social	Psychoacoustic impacts of NRD material selection
	Loss of view and sunlight because of the placement of NRDs for residents and road users
	Ability of the NRD to affect outside air circulation
	Vulnerability of the barrier to vandalism
	Ability of the noise barrier face to be used as community art projects
	Glare from the NRD to road users
Environmental	Noise barriers obstructing fauna/wildlife corridors
	Ability of the NRD to trap/deflect roadside pollution
	Accommodating water flow though the barrier under normal conditions (land use)
	Special drainage conditions to address flood risk (land use)

The questionnaire survey allowed the researchers to engage with a large range of relevant stakeholders involved throughout the whole life cycle of NRDs in a short space of time, and gain key feedback from the industry regarding their perceptions of sustainability criteria. It provided a platform for the stakeholders to get involved in developing a NRD sustainability assessment tool. However, the questionnaire results provide an overview of what is felt most important to key players connected with NRDs in Europe. The stakeholders are not, in general, experts in sustainability, their opinions inform research decisions, and so the survey results described cannot be considered definitive and used in isolation. Ultimately, it is for the experts in sustainability (i.e., the authors and the expert working group) to take into consideration all sources of information, i.e., the results of the literature review, stakeholders' feedback from the questionnaires, and the opinions of the expert working group, to define the final set of generic criteria that are most appropriate for assessing the sustainability of NRD projects.

In drawing conclusions, it needs to be remembered that the average ratings are based on different numbers of responses, which makes for difficulties in interpretations. However, the analysis of the ranking data was more robust because this was based on complete sets of data. Generally, there was good agreement among those who responded, which was shown to be statistically significant. Further, it was shown that these rankings were significantly correlated with average ratings of primary criteria in three out of the four groups of factors. In the fourth case (environmental criteria), in which there was no significant correlation, it was shown that there was no significant agreement among the rankings of respondents, probably because the criteria were considered of similar importance. It is considered that this good agreement between rankings and ratings lends support to using the average ratings as a means of ordering the importance of the whole set of criteria, both primary, secondary, and indicators.

Additionally, from the survey of stakeholders involved with NRDs, it was shown that broadly speaking, all the criteria identified from literature sources and stakeholder discussions have been rated moderately to very important. The rankings based on the replies from a detailed structured questionnaire provide a convenient summary of the relative importance of four factors and 22 primary criteria. These rankings will be of importance in assessing the overall sustainability of NRD projects in future procurement.

One important aspect for future consideration is the practicality of assessing the criteria. For assessing the overall sustainability of NRD project options, a clear MCDM for comparing all criteria in relationship to one another is required, and this will be the aim of the authors involved with the QUIESST (2010) project in the next phase. This will form the basis for outlining the sustainability assessment method for NRD projects, and so conclude the final NRD sustainability tool for designing and managing NRDs.

Overall Conclusion

The top-down-bottom-up methodology has been introduced and practically applied to define sustainability assessment criteria for unique civil engineering/infrastructure projects in this paper. Although there is disjointed literature describing different approaches to developing a sustainability assessment tool and so the subsequent assessment criteria are required, this paper has aimed to succinctly describe a methodology that synthesizes all major research methods to define sustainability assessment criteria specifically for unique civil engineering/infrastructure projects. This method will help inform stakeholders to define appropriate sustainability assessment criteria for projects when (1) the sustainability has not been widely considered for the project type; (2) the stakeholders wish to go through the process of defining their own sustainability criteria for appraising project options; (3) no industry accepted sustainability assessment tool, which addresses the technical, economic, environmental, and social factors of sustainability exists for the project type; and (4) the stakeholders wish to develop their own sustainability assessment tool instead of relying on prescriptive rating tools.

Two distinct approaches have been combined: the top down approach and the bottom up approach for defining criteria. The end result of applying the said TDBU methodology is a tenable set of criteria that denotes assessing the sustainability of the civil engineering project type in question. Such an approach is invariably more scientifically rigorous than defining criteria based on intuition or by a single/small group of decision makers without consultation. However, the methodology could be criticized as being largely technocratic in its approach because of the top down section defining sustainability for civil engineering projects (i.e., assessment goal), the sustainability assessment framework, selecting and creating the initial set of criteria, and affirming the final set of criteria following the stakeholders' engagement process by a single/expert group working on the project type. It is difficult to specify other stages stakeholders should/could be involved with because it is the authors' view that the axiomatic sustainability definition and framework should be fixed to provide a common approach. The bottom up aspect of the method focuses on consulting a large pool of stakeholders relevant to the project type through a number of participatory methods for further criteria creation, which is now becoming increasingly important to validate the selection and use of criteria for projects' evaluation and maximizing sustainability.

The value of the top-down-bottom-up methodology is evident from its application to define sustainability assessment criteria for NRD projects. Here, it was found that the review of the regulatory framework/EN standards/CE marking/design guides regarding NRDs, review of NRDs' sustainability literature, and interviews with key stakeholders proved to be the best methods to initially identify general and unique sustainability issues to consider and thus assess for NRD projects. It is likely unique issues to NRD projects such as assessing the impact NRDs have on obstructing fauna movements, the ability of NRDs to trap/deflect and so reduce roadside pollution, the effect the placement and type of NRDs have on nearby property prices and possible compensation costs payable, the modularity and ability of the NRD to change as required (for example, to increase the height of the noise barrier, should there be an increase in noise emissions because of an increase of vehicles on the road), the safety impacts of glare from the NRD to road users, the loss of view and sunlight because of the placement of NRDs for residents and road users, the ability of the NRD to affect outside air circulation, and the ability of the noise barrier face to be used as community art projects to increase social acceptance would not have been assessable criteria within the general sustainability assessment tools available for civil engineering projects, albeit the TBDU method could be implemented to add further criteria to already established tools (e.g., for SPeAR and CEEQUAL). This lends support to the need to take a bespoke approach to assessing the sustainability of civil engineering/infrastructure projects and affirms that a one size fits all generic set of sustainability assessment criteria to comprehensively assess the many different types of civil engineering projects is an impossibility.

Fulfilling or optimizing a particular criterion in isolation does not denote the sustainability of the civil engineering/infrastructure project in question (e.g., carbon footprint). Indeed, it is the combination of all sustainability criteria being used and measured in relation to one another within the defined sustainability framework that shows the relative sustainability of the project as a whole. Thus, without a clear multicriteria decision-making system for comparing all criteria in relation to one another and setting reference points, benchmarks, and optimum points for indicators (through modeling criteria), it would be very difficult to assess the sustainability of the project type. Because there are many methods for modeling and assessing criteria, the aim in future research would therefore be to develop a common approach to modeling all criteria appropriately for carrying out a sustainability MCA for a civil engineering context. The MCA method will need to be able to assess the selected multiple sustainability criteria in relation to one another in an equitable way for assessing the overall sustainability of the project type in question.

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Queries

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