CEDR Transnational Road Research Programme
Call 2020: Resource Efficiency and the Circular Economy

Funded by: Denmark, Ireland, Netherlands, Norway, Sweden, Switzerland and the United Kingdom

CERCOM
Circular Economy in Road COnstruction and Maintenance

Analysis of case studies – Best practice approach

Deliverable No. D4.4, May 2023

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CEDR Call 2021: Transnational Road Research Programme

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Circular Economy in Road COnstruction and Maintenance

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Due date of milestone: 31/05/2023
Actual submission date: 29/06/2023

Start date of project: 01/09/2021 End date of project: 31/08/2023

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Organization	Country
National road administrations	
Flemish Roads and Traffic Agency	Belgium
Transport Infrastructure Ireland	Ireland
Norwegian Public Roads Administration	Norway
Statens Vegvesen	Norge
Zavod za gradbeništvo	Slovenije
Swiss Confederation - DETEC – FEDRO	Suisse
Rijkswaterstaat	The Netherlands
State agency for restoration and development of infrastructure of Ukraine	Ukraine
National Highways	United Kingdom
Arup and Welsh Government	Wales
Welsh Government	Wales
CEDR	-
Road construction and maintenance stakeholders	
Nynas	Belgium
COLAS	France
Consiltant	Ireland
Ecofelsinea srl con Socio Unico	Italia
AsfaltNu C.V.	The Netherlands
Boskalis	The Netherlands
Dura Vermeer	The Netherlands
SGS INTRON	The Netherlands
Q8Research	The Netherlands
CELSA	United Kingdom
Aggregate Industries (Holcim)	United Kingdom
FM Conway	United Kingdom
Hanson	United Kingdom
Tarmac	United Kingdom

Executive Summary

This report forms deliverable D4.4 of the Circular Economy in Road COnstruction and Maintenance (CERCOM) project, funded under the CEDR 2020 Transnational Research Programme on Resource Efficiency and Circular Economy. The CERCOM project aims to deliver tools and supporting resources to assist National Road Administrations (NRAs) to adopt a more Resource Efficient (RE) approach to highway maintenance. This is consistent with the principles of a Circular Economy (CE) where greater emphasis is placed on reusing, repairing, repurposing and recycling materials, preserving their value through multiple lifecycles. This change forms the basis of the European Commission's plan for addressing climate change challenges and building a "greener, more digital and more resilient Europe".

The major objective of this report is to present the feedback gathered from members of the participating NRAs and road construction and maintenance stakeholders on the various tools developed as part of the CERCOM project. To accomplish this, virtual workshops were conducted and the feedback was gathered through menti® sessions and verbal discussions. Based on the feedback, it was understood that although there is interest in enabling circular procurement, there is a lack of systematic tools for quantification, and understanding of CE concepts in the domain of pavements is still at its nascent stage. In this regard, the NRAs and contractors found the CERCOM tools useful in supporting procurement of circular and RE pavement construction and maintenance solutions. Further, the stakeholders showed interest in understanding the risk-based analysis framework, methods to quantify different key performance indicators, need for high-quality data, and output sensitivities. The stakeholders also suggested the important topics that they would like included in the resource pack to suit different learning styles and address the requirement of different NRAs and other road construction/maintenance agencies. Overall, the workshops assisted in exploring avenues to further improve the usefulness and applicability of the developed tools/resources and helping to enhance communication between different parts of the organisations.

1 Introduction

The Circular Economy in Road COnstruction and Maintenance (CERCOM) project has developed innovative tools and resources, a risk-based analysis framework and management tool to facilitate a step change in the adoption of Resource Efficiency (RE) and Circular Economy (CE) principles in procurement, and a maturity matrix to support and track progress in the transition to CE and multi-life cycle management for use by the National Road Administrations (NRAs) across Europe. This report comprises Deliverable 4.4 of the project, which describes the outcomes from workshops with members of NRAs and industry (contractors and consultants) participants.

2 Scope

This report is an output of work packages 4 and 5 that covers aspects of work performed as part of CERCOM Task 4.4. Virtual workshops were conducted with stakeholders representing NRAs, contractors, and material suppliers. The consultations were aimed at exploring processes to further improve the usefulness and applicability of the developed tools and helping to enhance communication between different parts of the organisation(s). In addition, the insights gained from the case studies analysis, mainly regarding data requirements, output sensitivities and effectiveness of the indicators were demonstrated.

Section 3 presents the objectives of workshops, topics discussed, and feedback received from the participating NRAs and Section 4 from participating contractors, material suppliers, and road construction/maintenance stakeholders. Note that the feedback was gathered through menti® sessions in the workshops and verbal discussions.

3 NRA workshops

The virtual workshops for the NRAs were organized in two sessions, with the first session on the 20th of April 2023, and the second session on the 25th of April 2023. The duration of each session was 90 minutes and the first session was attended by a total of five participants, while the second session was attended by seven participants, representing different NRAs across the Europe and United Kingdom.

3.1 Objectives

The objectives of the workshops were:

- To inform the policy/decision-makers, technical experts, and procurement professionals about the potential of the tools in procuring circular pavement construction and maintenance solutions,
- To highlight identified barriers and areas of development, which may inform future policy,
- To receive feedback on the suitability of the tools in supporting the transition to circular procurement and improving resource efficiency, and
- To enable WP5 of the CERCOM project, which will develop resources and training materials, to be focussed to produce output that is helpful to NRAs.

3.2 Topics discussed and feedback

3.2.1 Define CE in context of pavements

The objectives of the CERCOM project were outlined to provide context and background for the workshop discussions (Connolly et al. 2022; Lamb et al. 2022). The goal of providing a means to assess current practice and the potential benefits of more circular solutions in increasing RE, minimizing waste, and reducing the use of virgin materials were outlined. The definition of CE in the context of pavement design and maintenance developed and used in the CERCOM project was also presented.

3.2.2 CERCOM maturity matrix

The maturity matrix is a framework that has been developed as part of the CERCOM project (Deliverable D2.1) to enable highway authorities to self-assess their progress in transitioning to CE. It enables NRAs to track progress made and identify areas for development. The seven themes in the matrix were presented (CE ambition, embedding CE, performance monitoring, standards, supply chain, business models, and circular procurement) together with an illustration of how the progress made within each theme could be assessed against nine defined stages: stage 1-3 (engaging in transition), stage 4-6 (early stages of practice), and stages 7-9 (active deployment). The guidelines for applying the framework and an example of the result from assessing one NRA were also presented.

Participants were asked three questions to understand how organisations were already measuring their progress in circularity, the appetite for a consistent approach for doing this, and for views on the CERCOM maturity matrix. The feedback gathered through the menti® for the maturity matrix in the two sessions is presented in Figure 1. Having a net-zero carbon target was the most frequently selected approach to transitioning to circular economy (67% of responses), followed by having a circularity policy (22%) and procurement policy [that includes circular economy criteria] (11%). No participants indicated that they had any of the following in place:

- Formal definition of CE
- Key Performance Indicators (KPIs)
- Business models that value CE in decision making
- Tools for assessing CE and RE

A high level of appetite was expressed for using a consistent approach, with the implication that the maturity matrix developed in the CERCOM project has the potential to meet a genuine need. Responses to the final question suggested that the maturity matrix could be useable, either with some changes (54% of responses) or in its current form (31%). A smaller number, 15%, of responses indicated it was not likely to be taken up in their organisations.

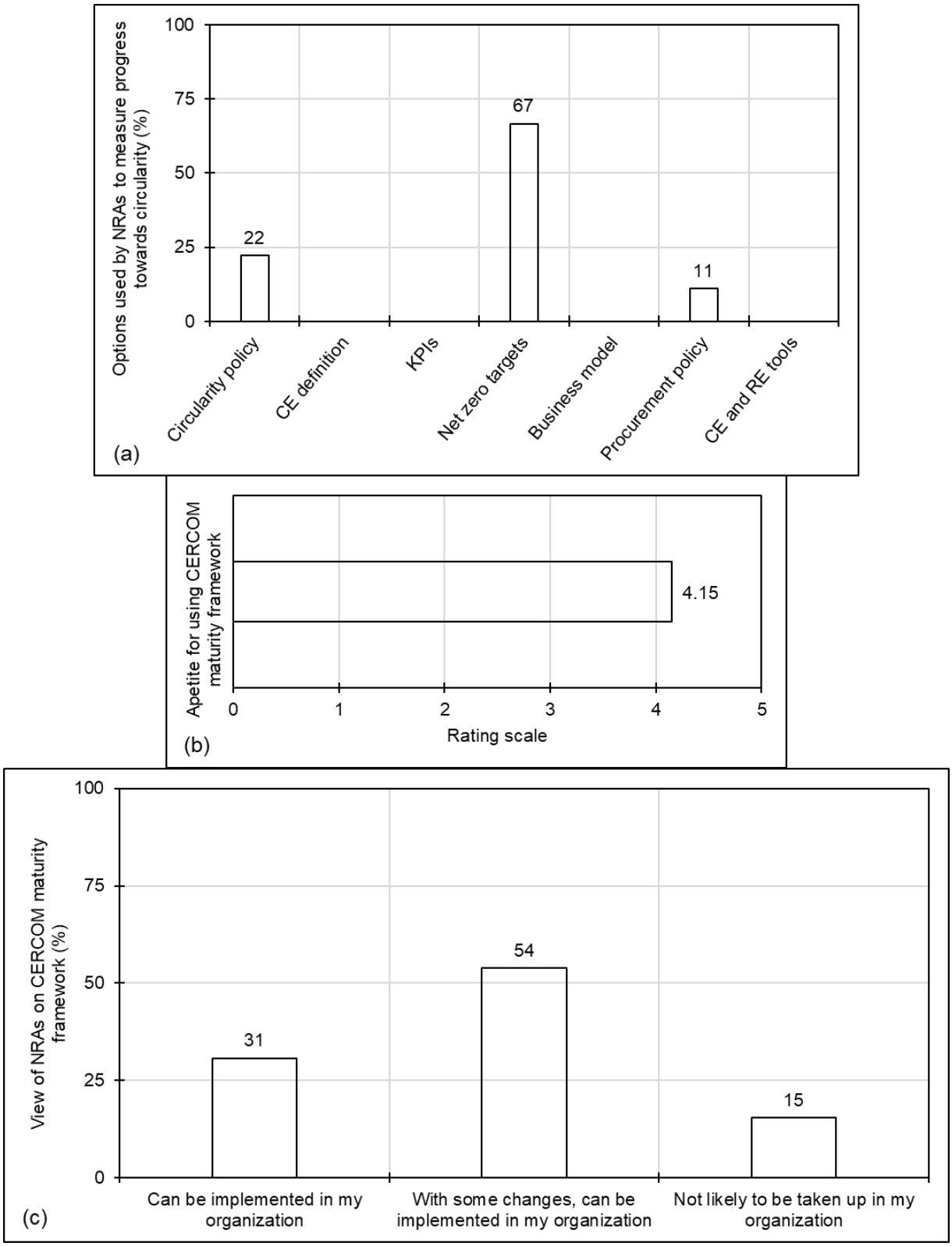


Figure 1. Feedback for Maturity Matrix: (a) Options to Measure Progress Towards Circularity, (b) Appetite for Using CERCOM Maturity Matrix, and (c) Scope for Implementation of CERCOM Maturity Framework in NRAs

3.2.3 *Developments to promote circularity in road construction and maintenance*

In this section of the workshop, six examples were presented of initiatives underway in different countries to promote circular practices. These initiatives are described in detail in deliverable D4.3, namely:

- Pathfinder projects (UK)
- Resource exchange mechanism (UK)
- New business model (Netherlands)
- Sweating the pavement asset (Ireland)
- Collaborative approach (Netherlands)
- Interactive decision tool (Sweden)

The questions to participants were aimed at understanding the level of interest in each of the initiatives presented and identifying further initiatives that were taking place. The feedback pertaining to recent developments aimed at promoting circularity in road construction and maintenance is provided in Figure 2.

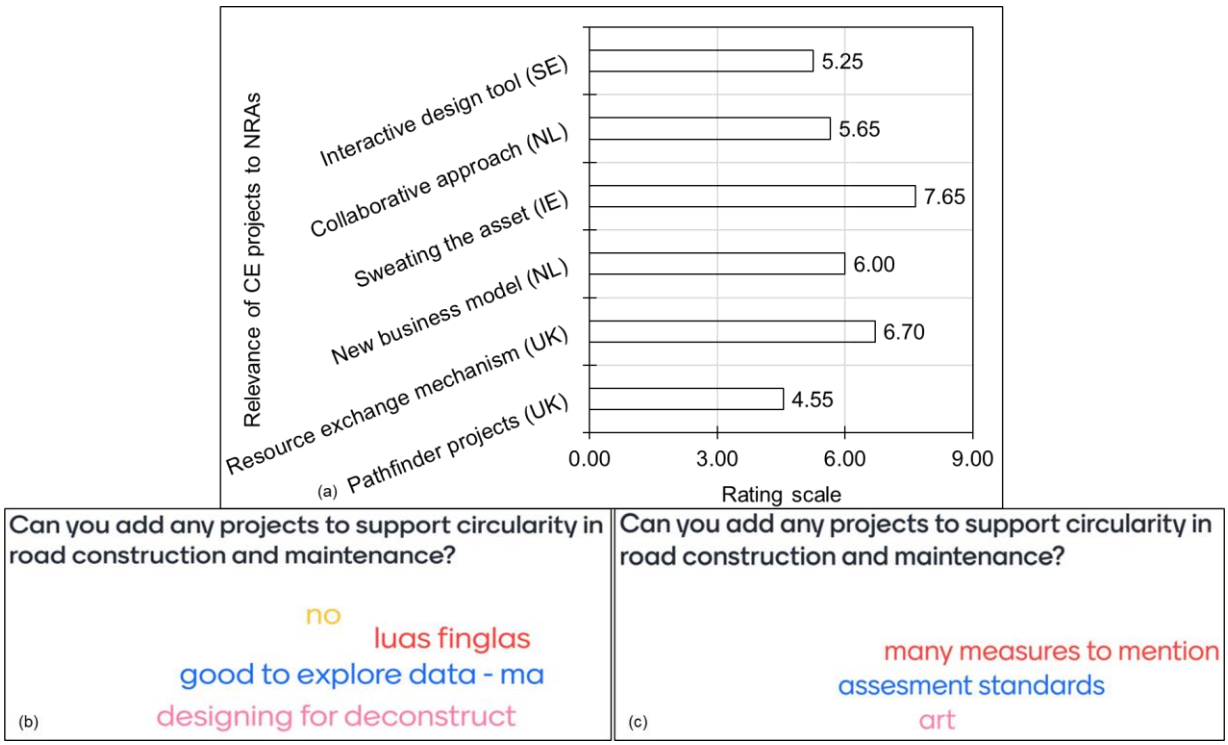


Figure 2. Feedback Pertinent to Circularity Initiatives in Road Infrastructure Sector: (a) relevance of CE projects to NRAs, and (b-c) other projects that support circularity

The responses to the first question, which was 'relevance of CE projects to NRAs', were variable: every initiative was found to be of significant interest to at least one participant, i.e., it was rated at a score of 8 or 9 on a 0-9 scale, while other participants had only a moderate interest, or no interest, in the same initiative. This most likely reflects the different priorities of the NRAs but also points towards value in establishing a varied 'toolbox' of different approaches and sharing experience of the variety of approaches being adopted.

Other examples of useful approaches suggested were:

- Luas Finglas – this is the proposed extension of the Luas Green Line in Dublin, Ireland.

- National bridges bank for re-use of bridges and parts of bridges (https://www.nationalebruggenbank.nl/) in the Netherlands.
- Efficient process management through the intelligent use of IT in (asphalt) road construction (https://www.uantwerpen.be/en/research-groups/emib/rers/projects/highlighted/road-it/) in Italy.
- Designing for deconstruction (no specific example was given)

3.2.4 CERCOM RBAF

The workshop attendees were guided through the objectives of the Risk Based Analysis Framework (RBAF) as well as the steps involved in the process. The categorisation of the criteria or KPIs to be incorporated into the RBAF were described. The participants were requested to provide feedback relating to criteria used to rank potential options when assessing tender documents. The feedback received from the two sessions is provided in Figure 3. It is clear from the average feedback that technical performance, economic performance and environmental impacts rank most highly, with social and circularity factors given less weight. It is envisaged that over time, as maturity grows and more data is available, a higher ranking would be assigned to circularity and resource efficiency by all NRAs.

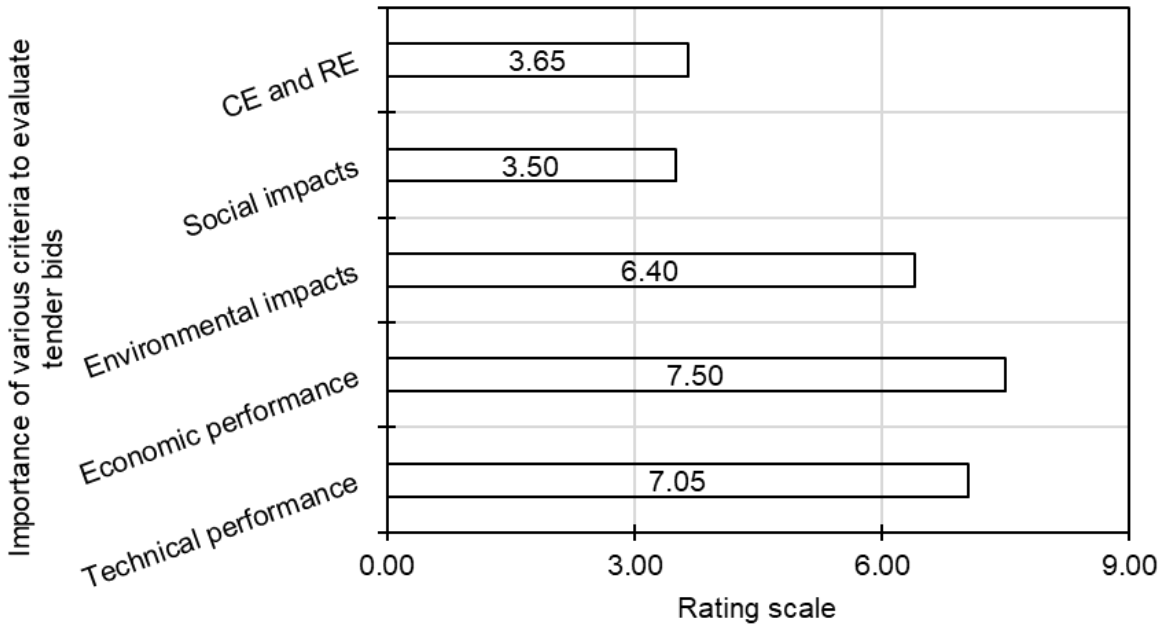


Figure 3. Importance of Different Criteria to Evaluate Tender Bids

The methods to incorporate data within the application of the RBAF were also discussed. The calculation and purpose of the Risk Reduction Index (*RRI*) was discussed, as well as the Cost Performance Index (*CPI*). The means to incorporate additional KPIs using the ranked interpolation method was also explained. The attendees were then asked to provide feedback on any potential software tools that contractors are required to use to assess particular tender criteria. The feedback received from the two sessions is provided in Figure 4. Again, there is a wide range of answers, with “Yes”, “No” and “Sometimes” all selected. When requested to provide the name of these tools, DuboCalc (DuboCalc Development Team 2023) and TII Carbon Tool (Transport Infrastructure Ireland 2022) were provided. This indicates the growing emphasis that is being placed on sustainability and environmental factors within the procurement process. Feedback indicates that the use of these tools is not always mandatory,

but the tools are available for use when preparing tender bids. It is envisaged that further tools of this nature will be developed as maturity grows.

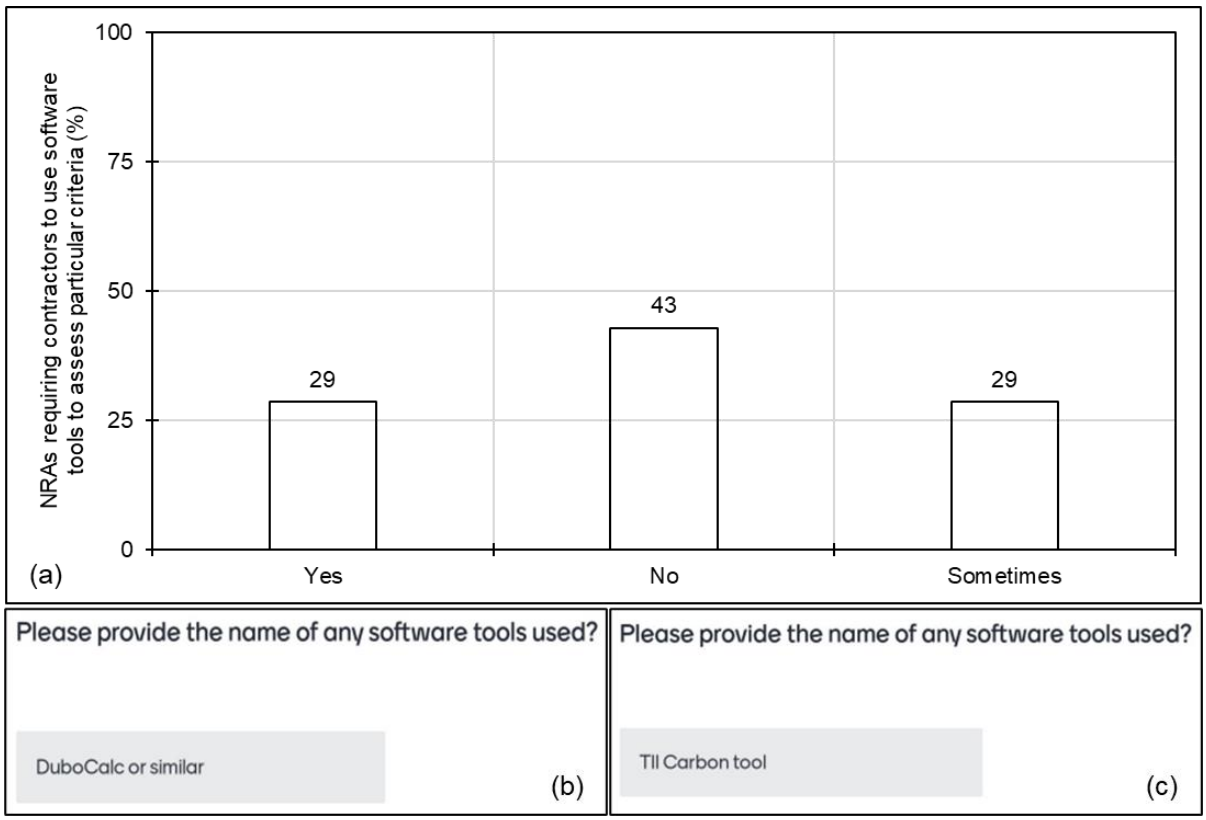


Figure 4. Assessment of Criteria Using Software Tools: (a) Software Requirements Specified by NRAs, and (b-c) Software Tools Used

Following a brief outline of the format and the structure of the software tool developed for application of the RBAF, the participants were asked to rank the format of training resources that would be preferable as part of the CERCOM resource pack. There were 5 options provided:

- Short video presentation (2-5 minutes)
- Long video presentation (15-20 minutes)
- PDF slides
- Video of software demonstration
- User manual

The feedback from both workshops is provided in Figure 5. Despite a wide spread of answers, the feedback received indicates that all resources suggested would prove useful, with the preference for format being down to personal choice. Taking an average of the answers of both sessions, the feedback suggests that a video demonstration of the software would be most beneficial. However, given variation in answers provided, the CERCOM project team will provide resources in all suggested formats. On average, the longer video (15 to 20 minutes) received the least positive feedback. On this basis, an alternative more concise video of approximately 12 minutes will be produced instead.

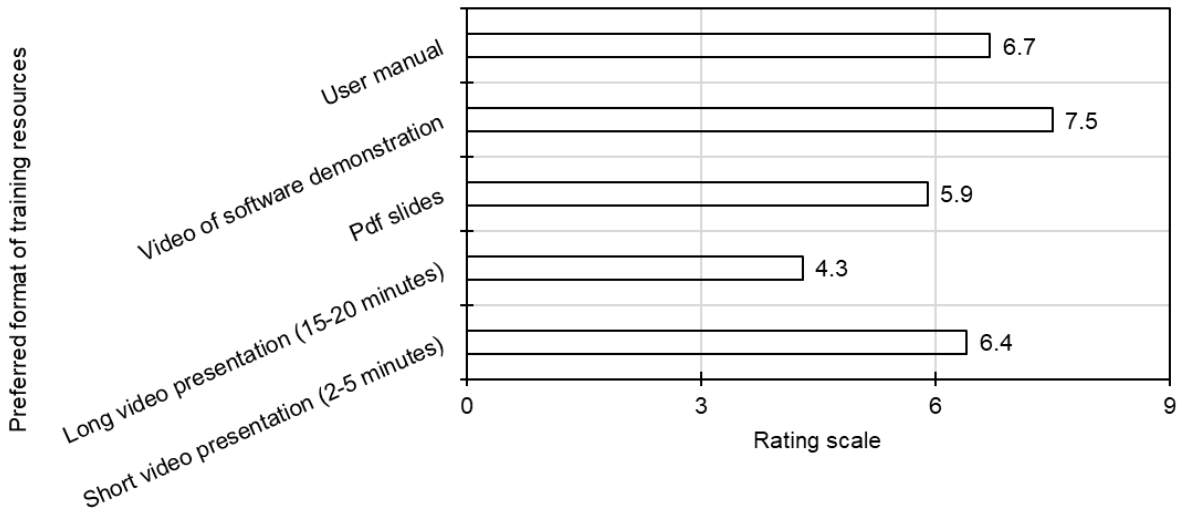


Figure 5. Preferable Format for Dissemination of RBAF Training Resources

3.2.5 Role of key performance indicators

The quality of lifecycle analysis data as well as its availability with the NRAs is presented in Figure 6. The responses by the NRAs reveal a relatively low to moderate score for both the availability and quality of data. A lack of quality data incurs a heightened uncertainty in the validity of results generated by the LCA model.

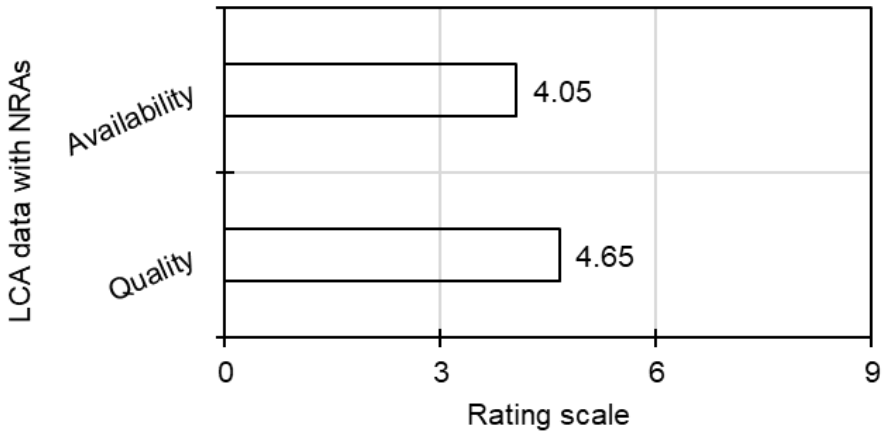


Figure 6. LCA Data Quality and Availability with NRAs

Availability of data is often a key barrier to performing accurate data analysis. CEDR's approach towards removing this barrier has been demonstrated through initiatives such as ARISE (ARISE 2016), INTERLINK (INTERLINK 2018), and most recently CoDEC (CoDEC 2021), which supports three key areas for improving data availability, namely:

1. Data harmonization through standardization of how data is collected, processed, and stored.
2. Employing digital data management systems.
3. Connecting and centralizing data management systems under a comprehensive asset management system, which can be queried via a web-platform.

Addressing data quality becomes more manageable once data has been standardized and made easily accessible. Initial LCAs can serve as a starting point to assess the quality and uncertainties associated with the available dataset. Further, the initial LCAs can assist in identification of missing information that may be required to perform futuristic analysis covering all the lifecycle phases. Once such data is identified, it can be integrated with the existing information to develop asset management plans specific to different pavement types and materials. LCA assesses data quality according to three metrics: geographic, temporal, and technological representativity. These three metrics are graded on a rubric of very poor, poor, fair, good, and very good. The LCA can also assess how sensitive the results are to incremental changes to data. Low quality data which is highly sensitive to the end results, should be prioritized for subsequent improvement.

3.2.6 CERCOM case studies - validation of the RBAF

This presentation in the workshop aimed at guiding the personnel of NRAs through the various steps of the RBAF through a case study on porous asphalt rejuvenation (Varveri et al. 2023). A series of questionnaire were posed to understand the measures taken by the NRAs to promote circular road construction and maintenance practices. The methodology for computation of KPIs was not presented and links of relevant resources (to understand the KPI computation) were shared with the attendees.

As can be seen in Figure 7, most of the NRAs admitted that the use phase and end-of-life of pavement infrastructure are given due consideration when assessing the circularity and sustainability credentials of different construction and maintenance schemes. Further, the different technical KPIs considered during the lifecycle of a pavement were listed as presented in Figure 8.

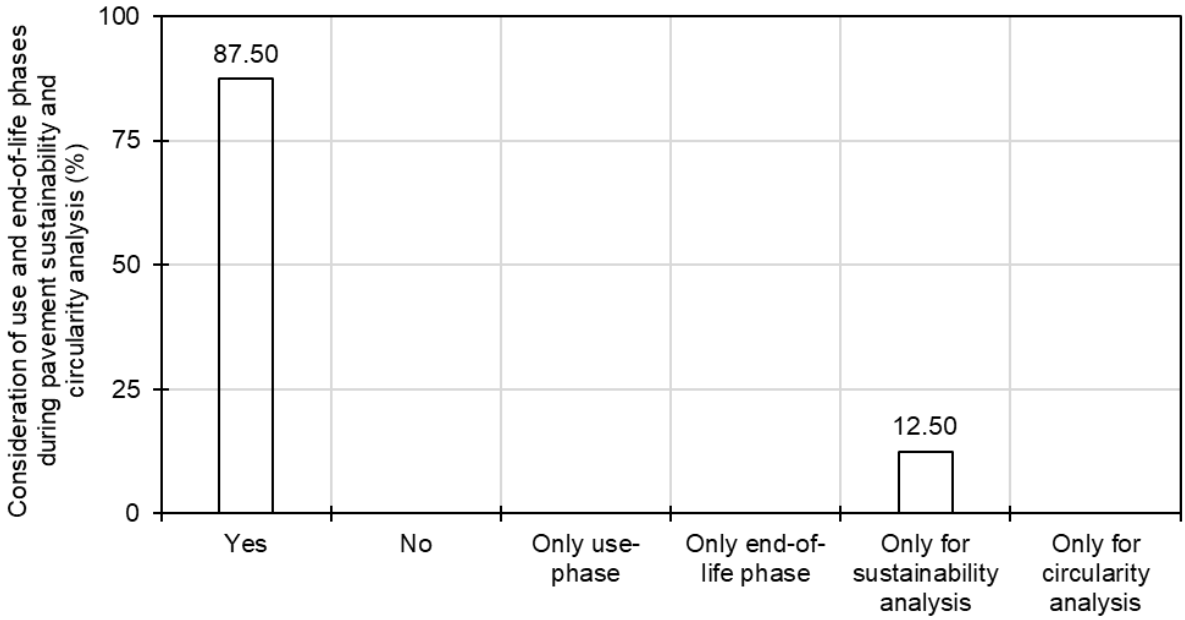


Figure 7. Feedback on Consideration of Different Lifecycle Phases

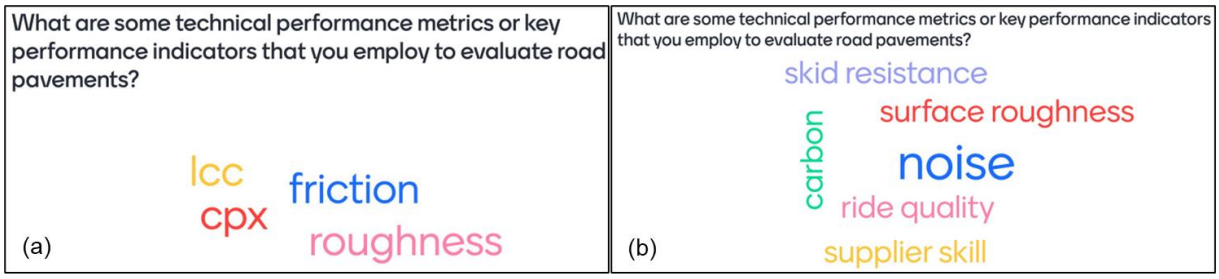


Figure 8. Technical KPIs Considered to Assess Pavement Performance Over its Lifecycle

The different economic, circularity, and social indicators utilized by the NRAs to assess pavement sustainability and circularity are presented in Figure 9 through Figure 11. Most of the NRAs were found to use benefit-cost ratio and the initial construction (capital) cost as the two metrics to assess the economic benefits of a pavement. Although capital cost can be a useful metric to assess the contribution of a construction/maintenance activity (prior to undertaking it) based on the allocated budgets, it does not dictate the economic benefit over the lifecycle. Some other metrics that are being used by a few NRAs include net present value and salvage value. It must be recalled from Deliverables 4.1 and 4.2 that net present value was used as the metric to assess the economic performance of different pavement construction and maintenance options. It is attributed to the fact that net present value is a comprehensive indicator, which considers the time value of money (i.e. can handle varying cash flows over the analysis period) and results in an absolute economic value, i.e., net profit or loss. On the other hand, benefit-cost ratio provides a ratio, i.e., a dimensionless quantity, which allows for easy comparison between the alternatives but does not explicitly consider the variation in cash flows owing to changes in the discount rate.

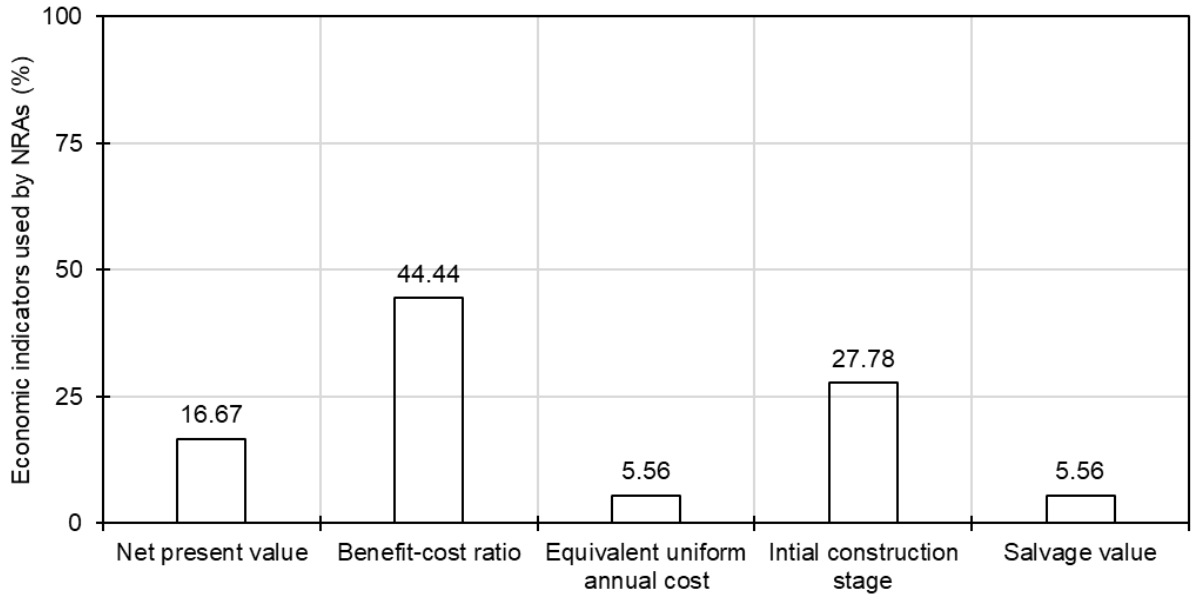


Figure 9. Economic Indicators Used by the NRAs

The circularity potential of different maintenance/construction options are being measured based on the proportion of recycled materials as can be seen in Figure 10. Though it is a relatively simple approach but lacks the consideration of durability aspects, which are related to the service life of pavement and govern the generation of recycled/waste feedstock.

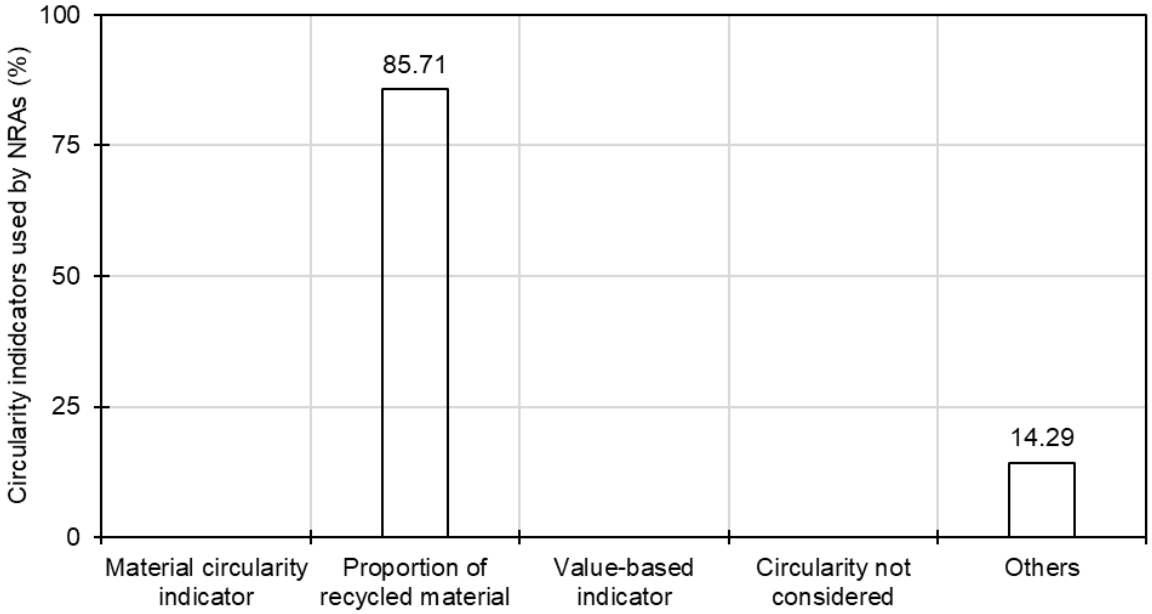


Figure 10. Circularity Indicators Used by the NRAs

The consideration of social impacts is an emerging concept as a few NRAs do consider it in the sustainability evaluation, while others use aspects such as road user delay, which can be accounted by the economic indicators (see Figure 11).

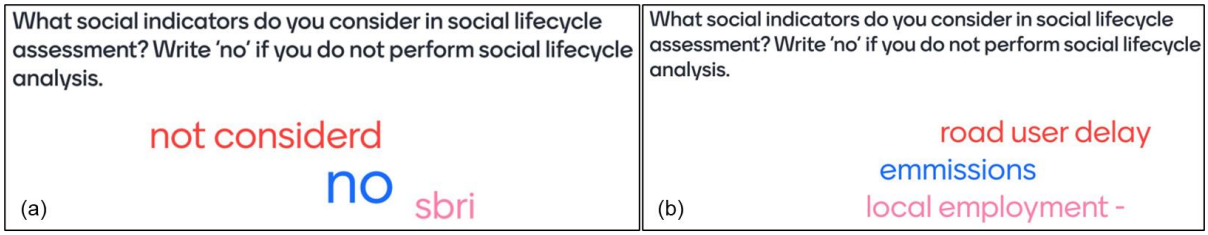


Figure 11. Social Indicators Used by the NRAs

As can be seen in Figure 12, the risks associated with a pavement construction/maintenance scheme are generally assessed through the related technical performance (e.g.: skid resistance) and economic aspects. It would be useful to evaluate risk by considering other technical performance aspects as well including but not limited to ravelling, cracking, etc., as the burdens associated with environmental, economic, social, and circularity facets are ultimately related to the initial design and the number of maintenance regimes over the lifecycle of a pavement.

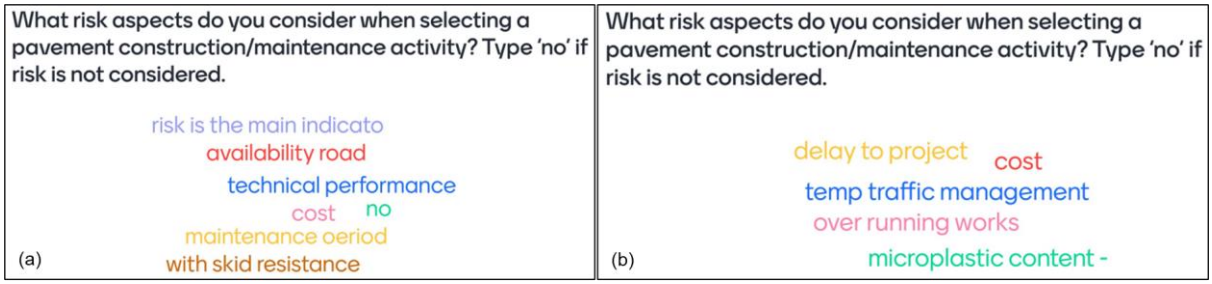


Figure 12. Risk Aspects Considered by the NRAs During Pavement Lifecycle

The information recorded by the NRAs during the service life of a pavement is presented in Figure 13. Essentially, the engagement between different stakeholders must be augmented to transition towards the development of time-dependent pavement performance prediction models, which could assist in better prediction of cumulative roadway impacts at the design phase itself.

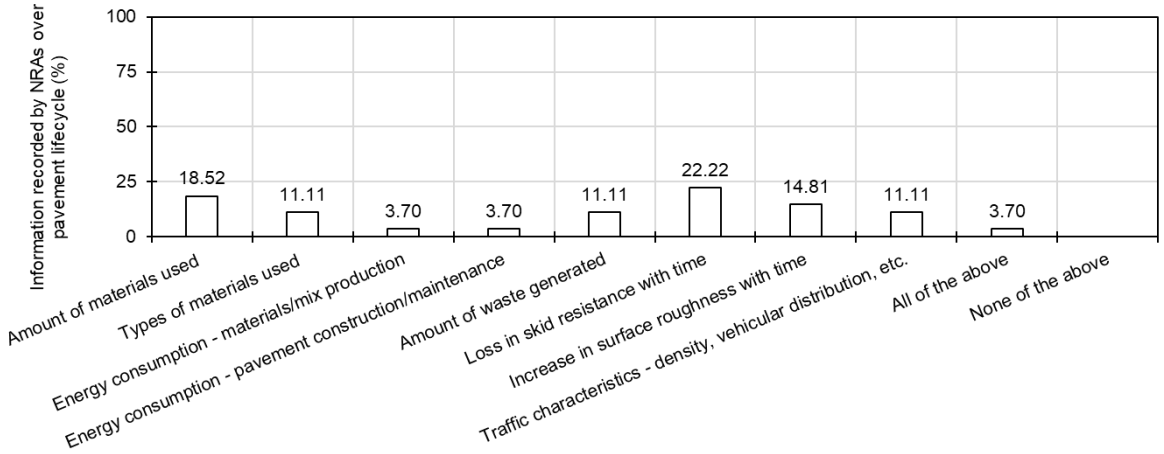


Figure 13. Data Collected During Lifecycle of a Pavement by the NRAs

Overall, it was understood that though there is enough thrust among the NRAs to integrate the sustainability, circularity, and technical aspects, there is limited understanding of the different advanced metrics that can be for their assessment as well as mechanisms (data collection, performance monitoring, etc.) that can facilitate circular procurement.

3.2.7 Benefits and implications of integrating RBAF in current procurement practices

As part of the CERCOM project, a roadmap for integration of the RBAF within procurement practices was also proposed. The workshops provided an excellent opportunity to gain feedback on the proposed implementation for NRAs of all maturity levels. It is clear from discussions throughout the project, that NRAs involved are currently at different levels of maturity. A schematic illustrating the potential implementation strategy was presented. Following this, the participants were asked to give an indication of the feasibility level of integration of the RBAF into procurement practices, both now and in the future. The responses are presented in Figure 14. The feedback shows some potential for use currently, with a significantly higher potential for implementation in the future. It is encouraging to see that participants recognise the potential benefits of the RBAF and software tool. It is anticipated that this would increase further following the availability of various training resources.

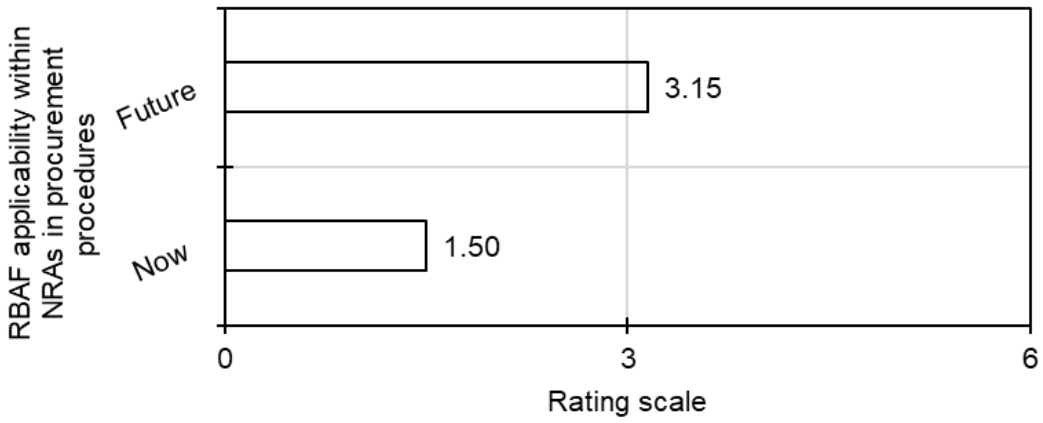


Figure 14. Extent of Applicability of RBAF Tool in Procurement Process

Attendees were then invited to suggest which members of their organisation would find the tool useful, with the results illustrated in Figure 15. In both sessions, procurement team, design team and management team were selected, with the option “other” selected in one session. No further details were provided by the attendee to indicate which “other” members in the organisation would find the tool beneficial. The results again reflect the variation in maturity of different NRAs and the flexibility of the tool to cater for all levels of maturity. For a higher level of maturity, and where more quality data is available, it is envisaged that the tool would be used primarily by procurement personnel when preparing tender documents and evaluating tender bids. Whereas, for lower levels of maturity, where there may be more uncertainty regarding data inputs, the tool can be used internally by design and management teams to give an indication of the potential benefits of various scheme options.

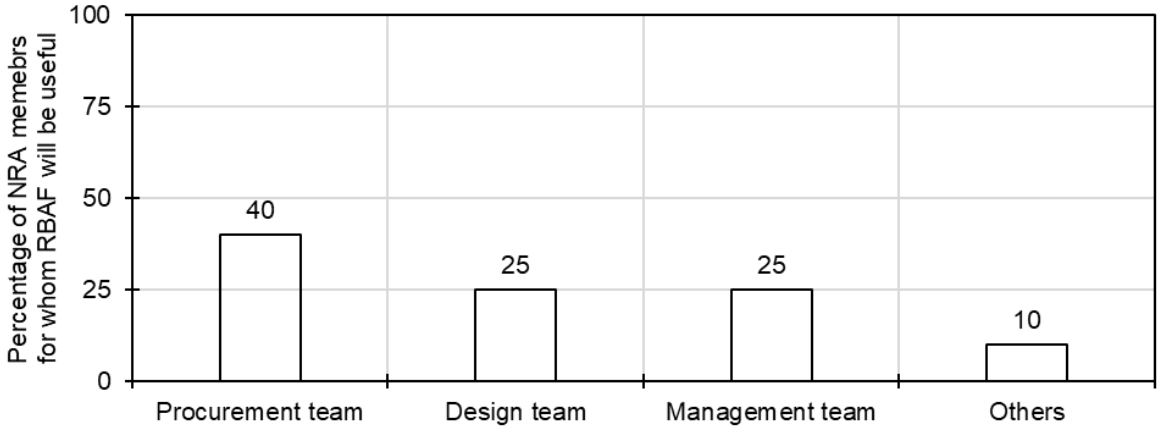


Figure 15. Suitability of RBAF Tool for Different NRA Members

As part of the workshops, it was imperative to gain as much insight as possible into the potential barriers to implementation of the RBAF in current procurement processes. The attendees were invited to rank proposed potential barriers and the results are illustrated in Figure 16. The following options were provided for ranking:

- Time/resource constraints
- Inexperience of NRAs with RBAF
- Lack of data
- Sensitivity of data

- Standards
- Other

Consolidating the results from both sessions, on average, time/resource constraints, inexperience using the tool and lack of data barriers were ranked comparably as the top 3 barriers. Barriers due to sensitivity of data and restrictions in current standards were ranked 4th and 5th (interchanged for the two sessions). Participants were also invited to provide additional details of potential barriers if the option "Other" was selected. The following additional barriers were raised:

- Competence
- Transparency
- Quality of data
- Lack of options for verification
- Unclear what CE indicator will be leading

The feedback highlights the importance of collating sufficient quality data to provide a robust means to generate KPI values to be integrated within the RBAF. Although not ranked among the top three barriers, the sensitivity of data is also a concern, especially regarding economic factors for emerging innovative approaches.

From discussions with NRAs over the course of the project, it is evident that functional specifications are being adopted in some countries and standards are being amended to allow for the integration of more circular solutions. It is envisaged that over time, these initiatives will spread to all NRAs as maturity develops.

Regarding inexperience of NRAs with use of the RBAF and time/resource constraints, it is anticipated that the resource pack developed as part of Work Package 5 will provide a means to reduce these barriers. It will provide resources in different formats, demonstrating the user-friendly methodology that was adopted when developing the software tool. It is recognised that time and resources for training are limited. The developed content will therefore be concise and intuitive to reduce the resource demands and increase confidence to overcome the barriers for implementation. The training resources will clearly outline how the software tool works, what inputs are required by the user and provide transparency on how the optimisation is carried out. As datasets grow, standard threshold values should be identified for various criteria to ensure consistency in assigning KPI values for each option. It is envisaged that this data, along with weights assigned to each criterion will be outlined in the tender documents and specification. This will provide a transparent robust method for calculating KPI values and optimising potential scheme options.

The feedback regarding CE indicators is also very useful and relevant. There are multiple CE indicators developed to date (e.g., Material Circularity Indicator (MCI)), but not all are suitable for use within the road infrastructure sector. As discussed as part of the CERCOM case studies, there are benefits to using both mass-based indicators and value-based indicators, depending on the scheme being considered. Further development and standardisation within this area would be beneficial for implementation of the RBAF.

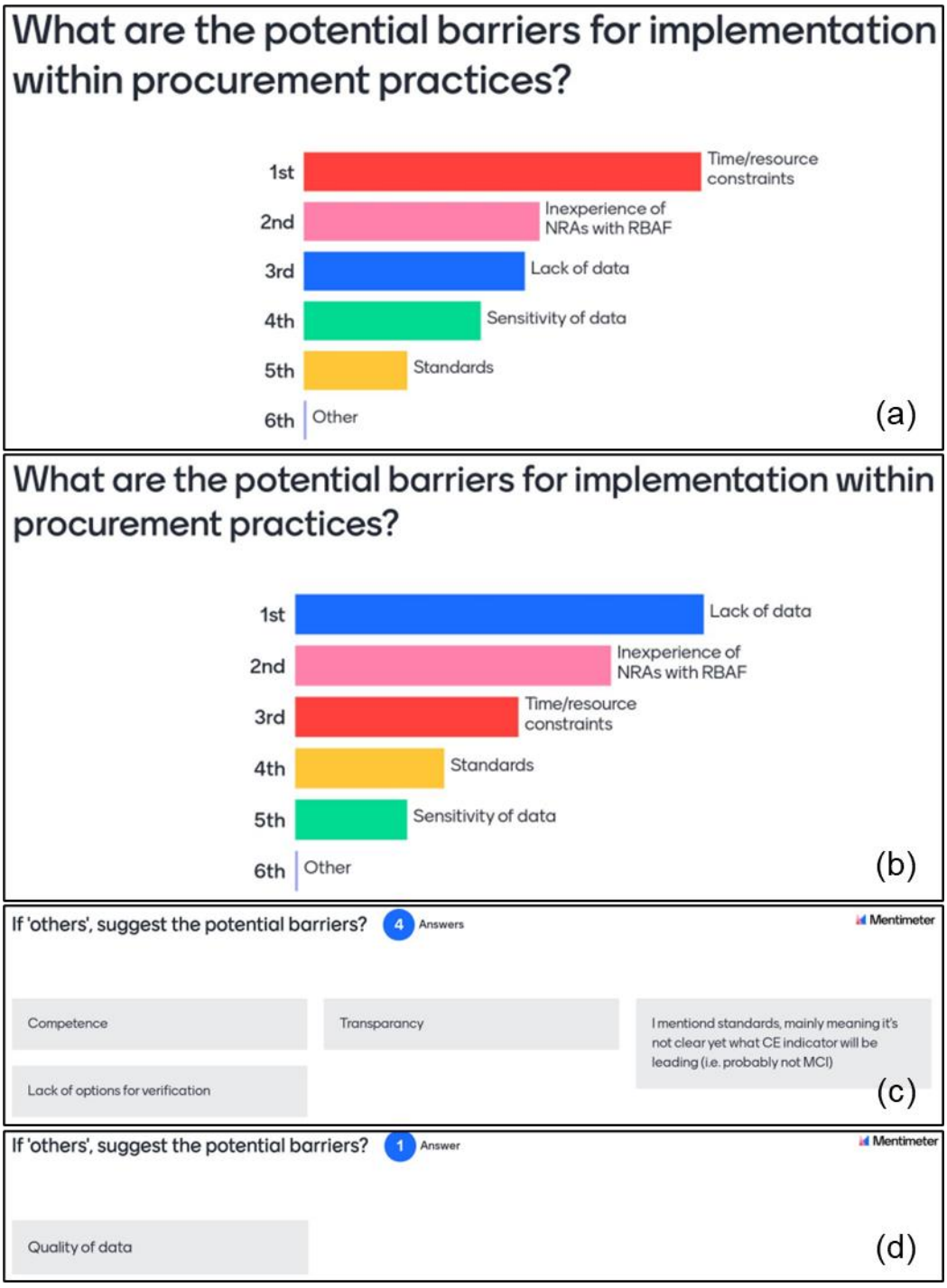


Figure 16. Barriers for Implementation of RBAF Within Current Procurement Practices: (a-b) Ranking Proposed Barriers, and (c-d) Other Barriers

3.2.8 Developing tender specifications to facilitate circularity and resource efficiency

Participants were asked two questions to understand how these concepts were influencing procurement policy in their organisations. Figure 17 presents the influence of net zero and CE targets along with examples on the procurement progress.

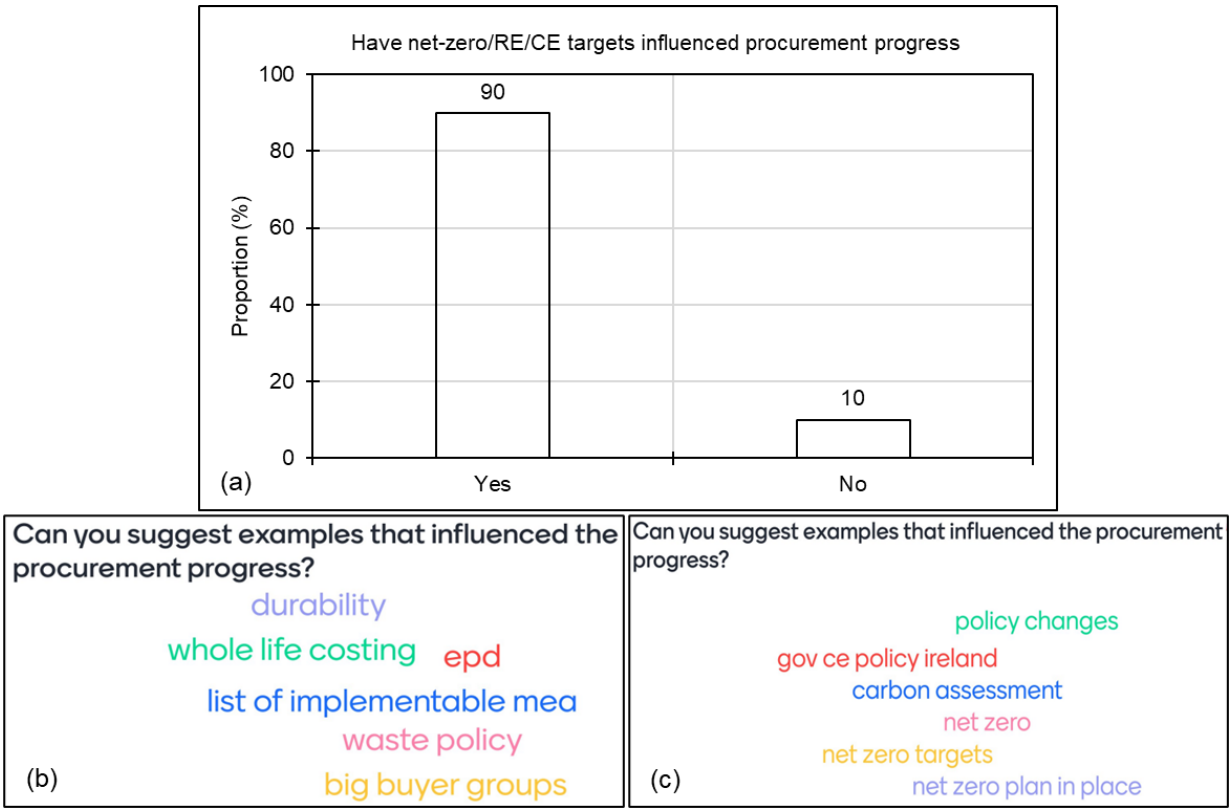


Figure 17. Influence of Net Zero and Circularity Targets on Procurement Progress

A large majority, 90% of respondents indicated that either net zero, RE/CE targets were already influencing procurement policy, with specific examples including:

- durability / whole life costing – reflecting the need to optimise the value provided by material resources through lifecycle
- carbon assessment / environmental product declaration / waste policy – reflecting the rounded assessment of impacts, dominated by carbon / net zero targets

Developing tender specifications that are explicitly targeted to address circularity and resource efficiency appears to be in the early stages although it is encouraging that key aspects that will drive the progress to circularity, net zero targets and whole life costing are becoming integral to procurement policy.

3.2.9 Contents of resource pack to support circular procurement

CERCOM WP5 will produce a resource pack to support NRAs in their transition to circular procurement. The planned content of this was presented to workshop participants, together with questions intended to highlight any important additions and to understand the format that would be preferred. The feedback on resource pack is presented in Figure 18 and Figure 19.

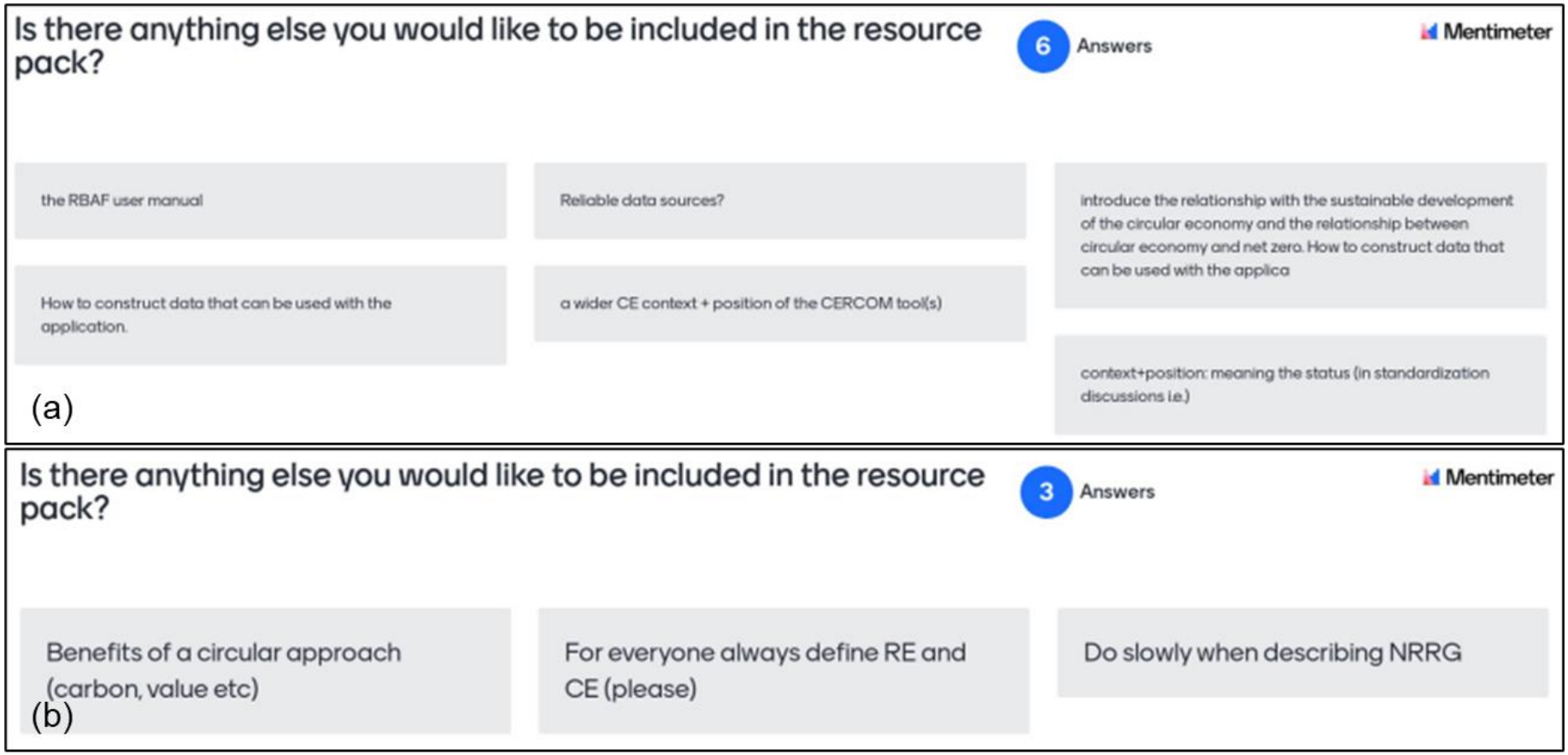


Figure 18. NRA Requirements in the Resource Pack

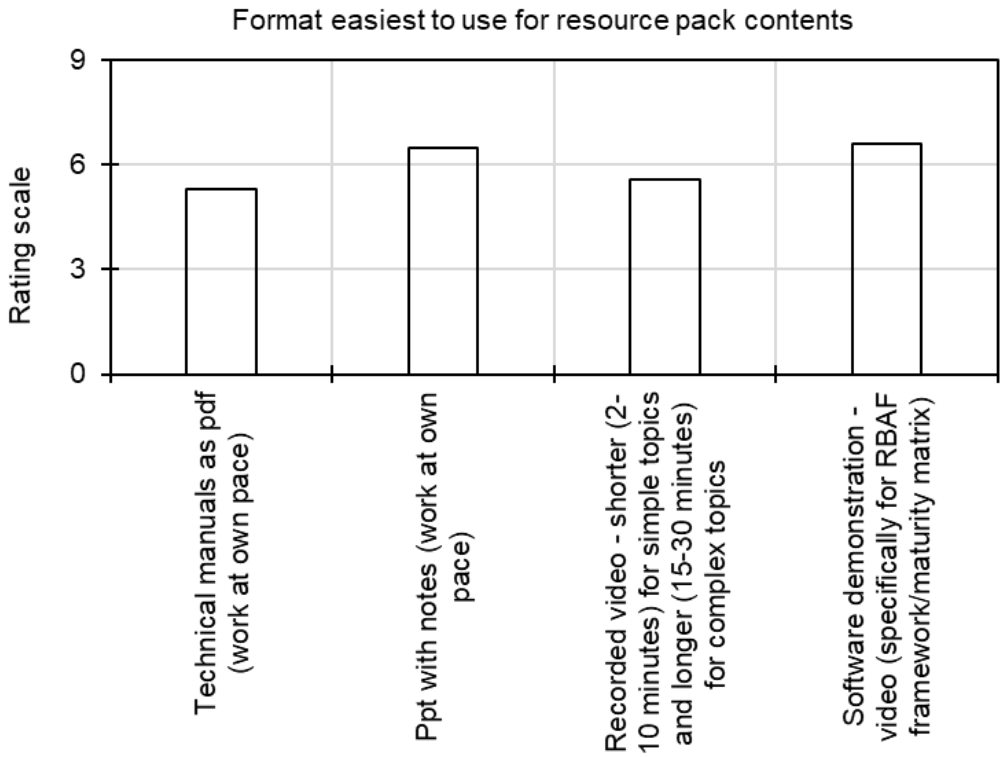


Figure 19. Anticipated Format of Training Resources

The following areas were identified as important to include in the resource pack:

- Definition of RE and CE; benefits of a circular approach (e.g. in reducing carbon plus wider sustainability benefits)
- Sources of reliable data
- RBAF user manual; making this very technical topic easy-to-understand

The responses on the preferred format of materials were varied. For each format suggested, some participants rated it as easier to use and some participants rated it as more difficult. This suggests that a range of formats should be included, to suit different learning styles.

4 Contractor workshop highlights

The virtual workshop for the material suppliers and road construction and maintenance stakeholders were organized in a single session on April 24th, 2023, between 11:00 a.m. and 12:30 p.m. The session was attended by a total of four participants from the Netherlands and Belgium.

4.1 Objectives

- To educate the contractors, material suppliers, and industry stakeholders about the potential of the RBAF in selecting circular pavement construction and maintenance solutions, and
- To receive feedback on the suitability of the RBAF to propose circular and resource efficient options for tendering processes.

4.2 Topics discussed and feedback

4.2.1 Define CE in context of pavements

The objectives of the CERCOM project were outlined to provide context and background for the workshop discussions. The goal of providing a means to assess current practice and the potential benefits of more circular solutions in increasing RE, minimizing waste and reducing the use of virgin materials were outlined. The definition of CE in the context of pavement design and maintenance developed and used in the CERCOM project was also presented.

4.2.2 Developments to promote circularity in road construction and maintenance

The same initiatives presented in the NRA workshops were also presented to the contractors for their feedback. The relevance of CE project examples pertaining to road construction and maintenance organizations is highlighted in Figure 20. As from the feedback from the NRA workshops, there was interest in all of the initiatives described, as well as additional suggestions made.

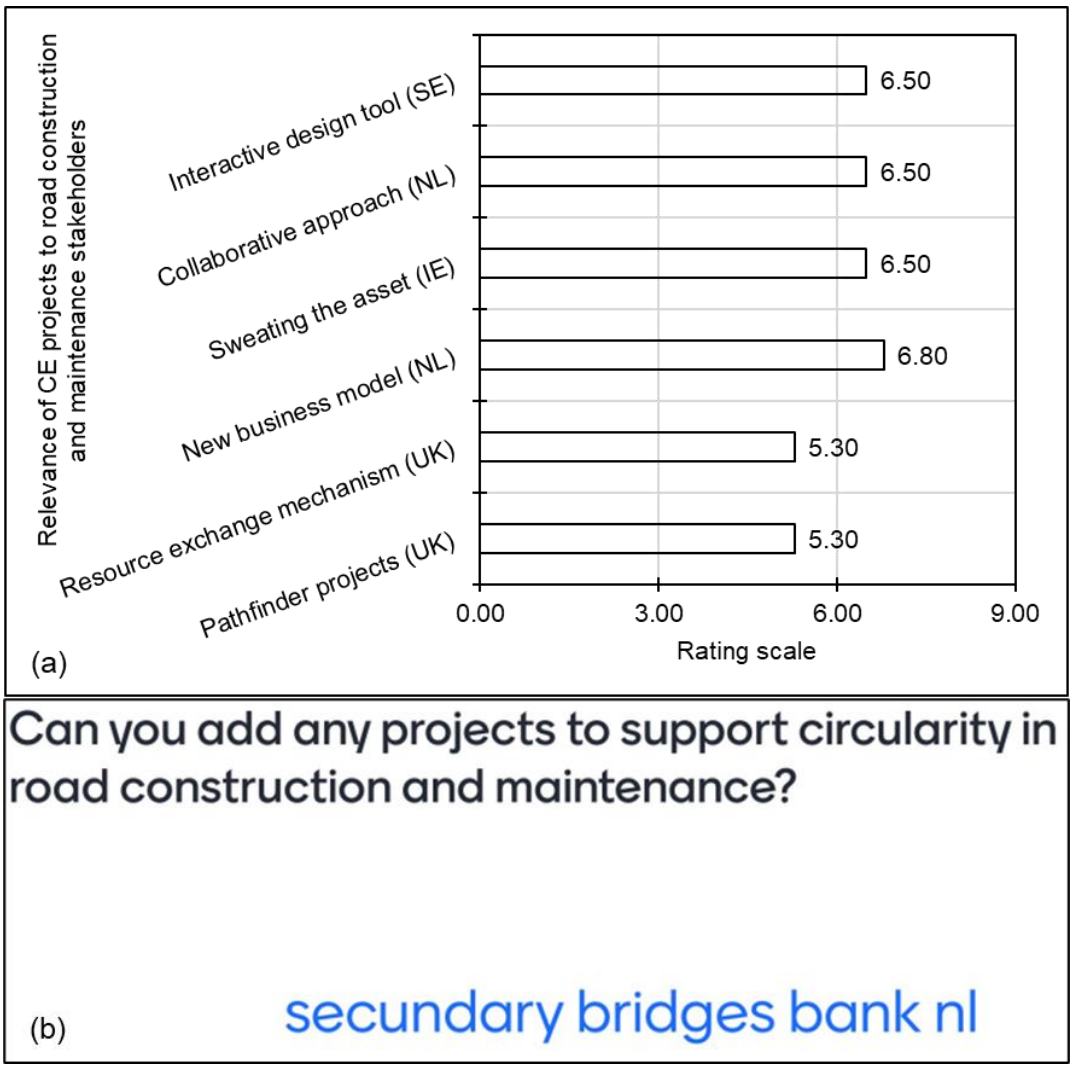


Figure 20. Circularity Projects: (a) Ranking the Relevance of Proposed Projects, and (b) Other Projects

4.2.3 CERCOM risk-based analysis framework

The workshop attendees were guided through the objectives of the Risk Based Analysis Framework (RBAF) as well as the steps involved in the process. The categorisation of the criteria or KPIs to be incorporated into the RBAF were described. The participants were requested to provide feedback relating to criteria that is generally ranked as part of tender bid evaluation. The feedback received is provided in Figure 21. It is clear from the feedback that technical performance and economic performance are given most weight as part of the tendering process. Environmental impacts, social impacts and circularity factors are ranked lower. However, the results do indicate quite a lot of variability between participants, with a wide spread in ranks selected for each criteria. This can potentially be attributed to the varying type of projects that contractors have bids for. It is possible that some contractors are involved in pathfinder projects, where a greater emphasis is being place on environmental and circularity factors. It is envisaged that over time as more data is collated, standards progress and functional specifications are adopted, a higher ranking would be assigned to circularity and resource efficiency across all countries involved.

The methods to incorporate data within the application of the RBAF were also discussed. The calculation and purpose of the Risk Reduction Index (*RRI*) was discussed, as well as the Cost Performance Index (*CPI*). The means to incorporate additional KPIs using the ranked interpolation method was also explained. The attendees were then asked to provide feedback on any potential software tools that NRAs require contractors to use to assess particular tender criteria. The feedback received is provided in Figure 21. Two participants answered “Yes” and one participant answered “Sometimes”. When requested to provide the name of these tools, DuboCalc (DuboCalc Development Team 2023) was provided. The results indicate the growing emphasis that is being placed on sustainability and environmental factors within the procurement process. Feedback indicates that the use of these tools is not always mandatory, but the tools are available for use when preparing tender bids.

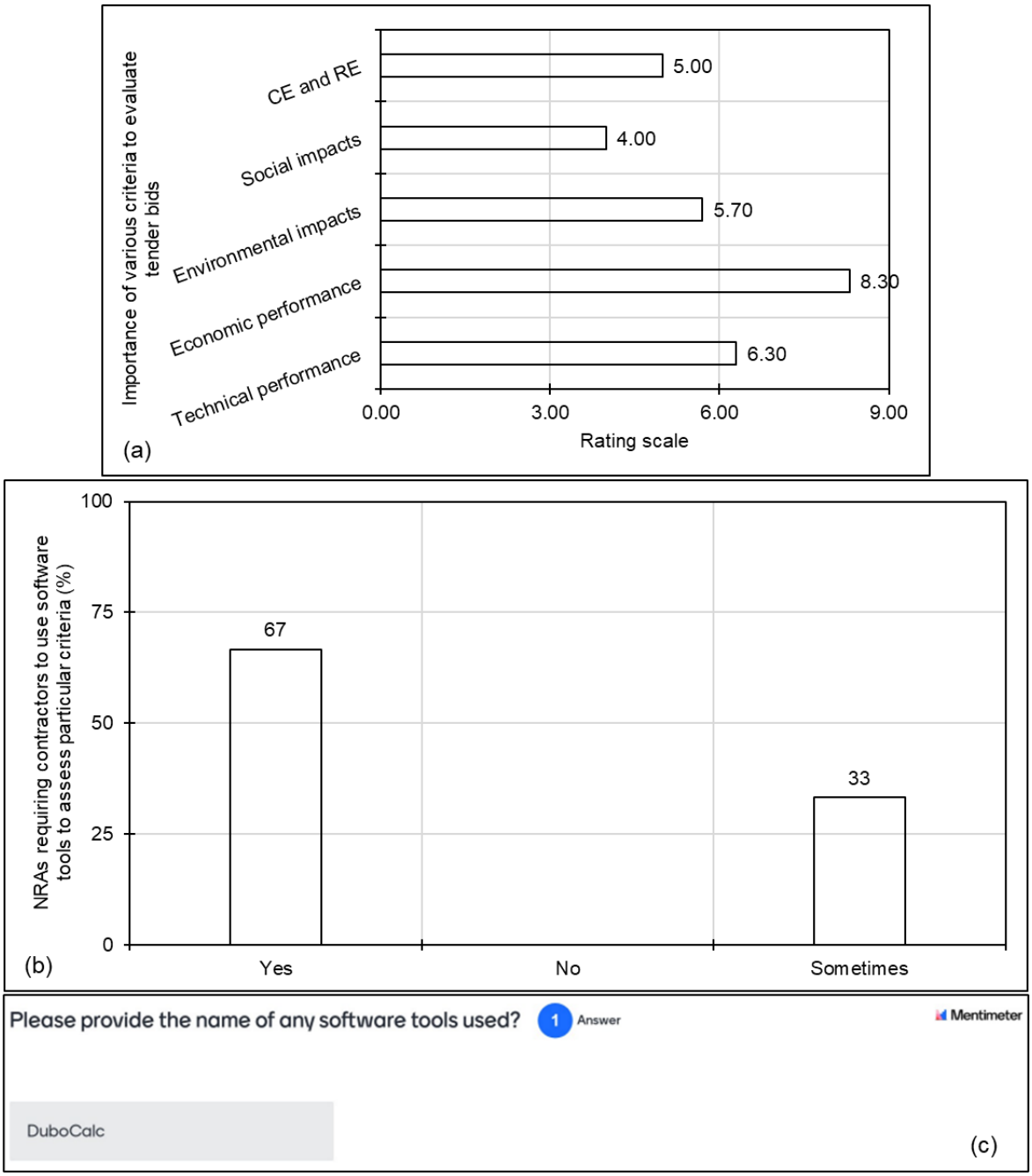


Figure 21. Criteria for Tendering Process and Software Tools for Analysis: (a) Ranking the Criteria Based on Importance, (b) NRAs Requirements to Use Software Tools, and (c) Software Tools

Following a brief outline of the format and the structure of the software tool developed for application of the RBAF, the participants were asked to rank the format of training resources that would be preferable as part of the CERCOM resource pack. There were 5 options provided:

- Short video presentation (2-5 minutes)
- Long video presentation (15-20 minutes)
- PDF slides
- Video of software demonstration
- User manual

The results are provided in Figure 22. Despite the wide range of answers, feedback received indicates that all resources suggested would prove useful, with a short video presentation, a video of software demonstration and a user manual would be most beneficial. However, given variation in answers provided, the CERCOM project team will provide resources in all suggested formats. The longer video (15 to 20 minutes) received the least positive feedback. On this basis, an alternative more concise video of approximately 12 minutes will be produced instead.

Based on the brief outline of the RBAF and the software tool provided within the workshop, the participants were asked to give an indication of the feasibility level of integration of the RBAF into their organisation to rank potential construction/maintenance options, both now and in the future. The responses are presented in Figure 22. The feedback shows some potential for use currently, with a significantly higher potential for implementation in the future. It is encouraging to see that participants recognise the potential benefits of the RBAF and software tool. It is anticipated that this would increase further following the availability of various training resources.

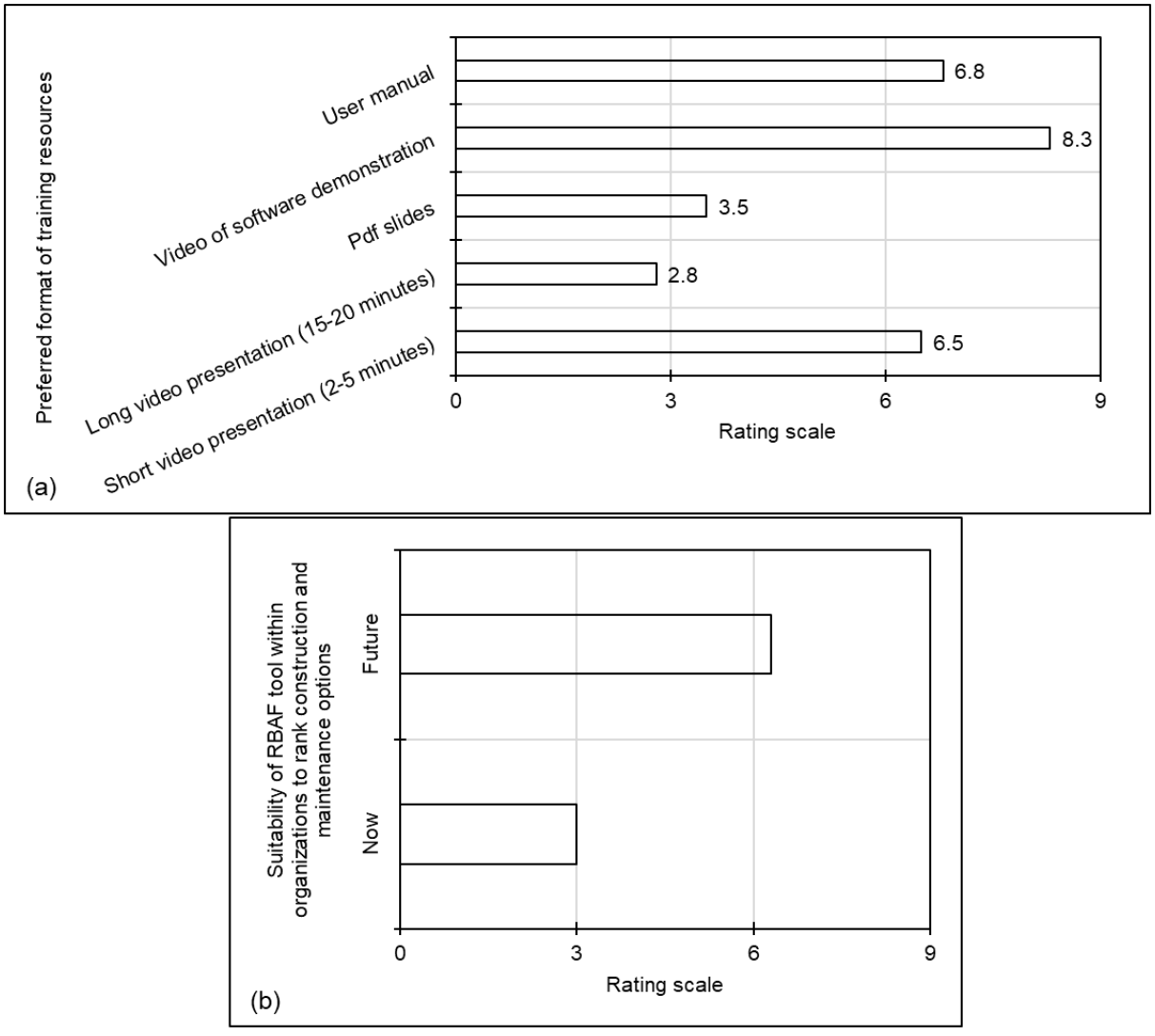


Figure 22. Anticipated Format of RBAF Training Resources and its Potential of Applicability

4.2.4 Role of key performance indicators

The quality of lifecycle analysis data as well as its availability with the contractors is presented in Figure 23. The figure shows a high level of both quality and availability from the contractors, which shows that they are typically ready to provide data for the RBAF. The numbers correlate with the general trend of product LCA's that are required for some tenders. The disparity of scores between contractors and NRA's highlights the need for building and improving digital infrastructure for connecting and incorporating data from industry into a centralized asset management system.

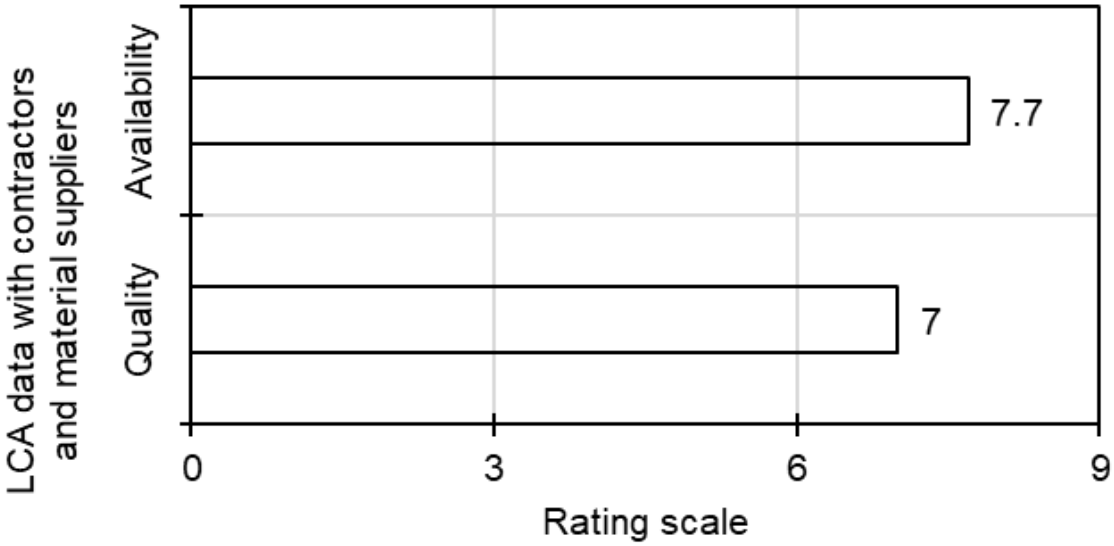


Figure 23. Lifecycle Data Quality and Availability with Road Construction and Maintenance Stakeholders

4.2.5 CERCOM case studies - validation of RBAF

The feedback relevant to the consideration of use and end-of-life phases as well as technical KPIs to evaluate the pavement performance is presented in Figure 24. As can be seen, the consideration of circularity while submitting tender bids is still in its nascent stages and highlights the urgency for development of frameworks and systematic methodologies (to compute KPIs) formulated as part of the CERCOM RBAF.

The different economic, circularity, and social indicators utilized by the NRAs to assess pavement sustainability and circularity are presented in Figure 25. As expected, benefit-cost ratio and capital cost are being used as two metrics to assess the economic performance. Further, the proportion of recycled materials is the only indicative measure that is being used by the contractors to assess circularity levels of their construction/maintenance methods. These trends are clearly driven by the tender requirements formulated by the NRAs, thereby indicating the need to introduce a step change in the tendering process to allow adoption of diversified and comprehensive metrics, which will eventually facilitate in robust, sustainable, and circular decision-making. Furthermore, the social impacts are governed by the safety of workers and gender equality. Although these are important social indicators, there are several other indices that must be integrated in the social lifecycle analysis as already presented in Deliverables 4.1 and 4.2.

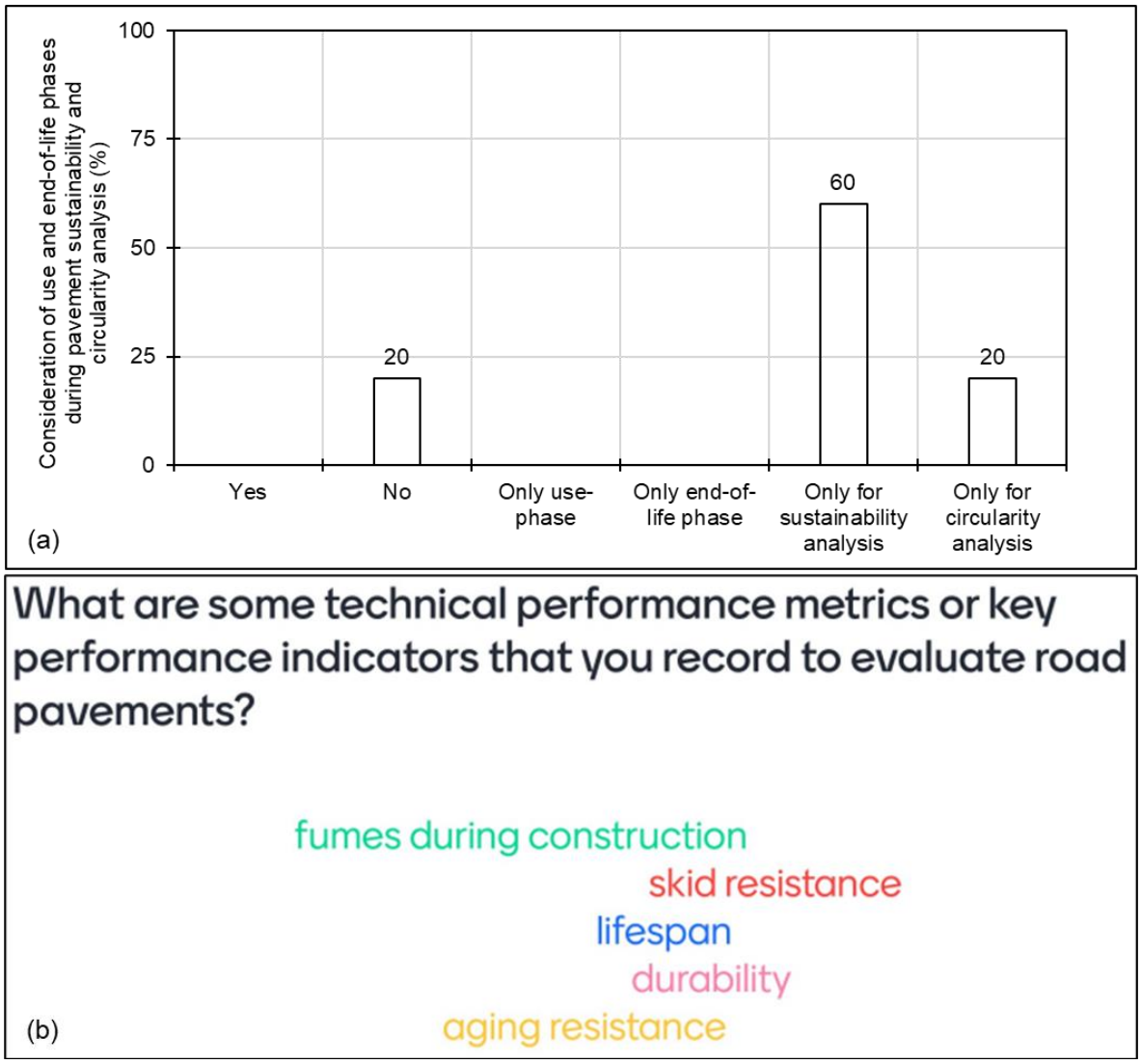
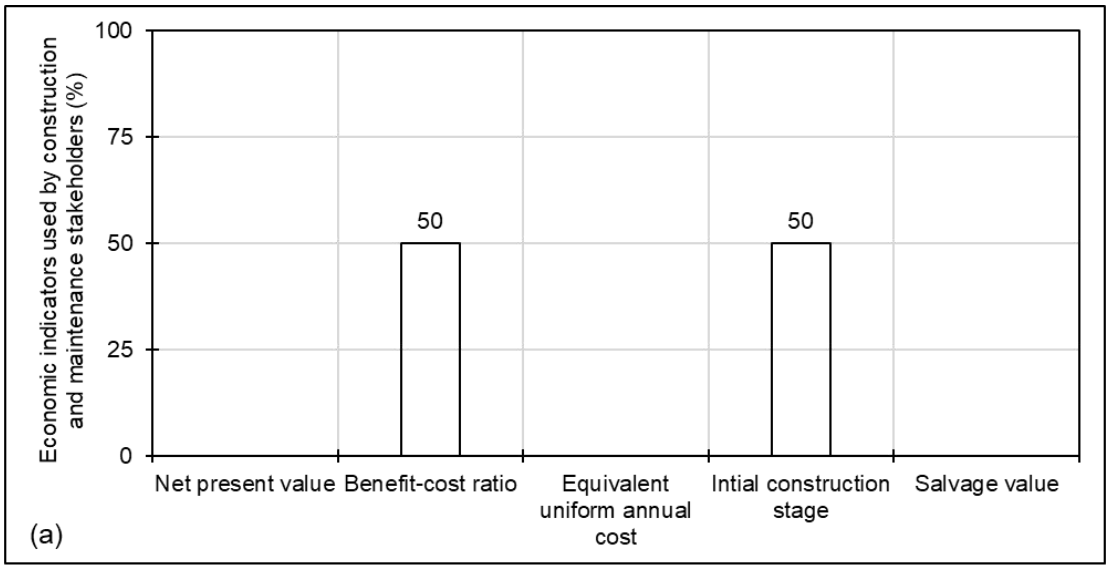


Figure 24. Feedback on Consideration of Different Lifecycle Phases and Technical KPIs to Evaluate Pavement Performance



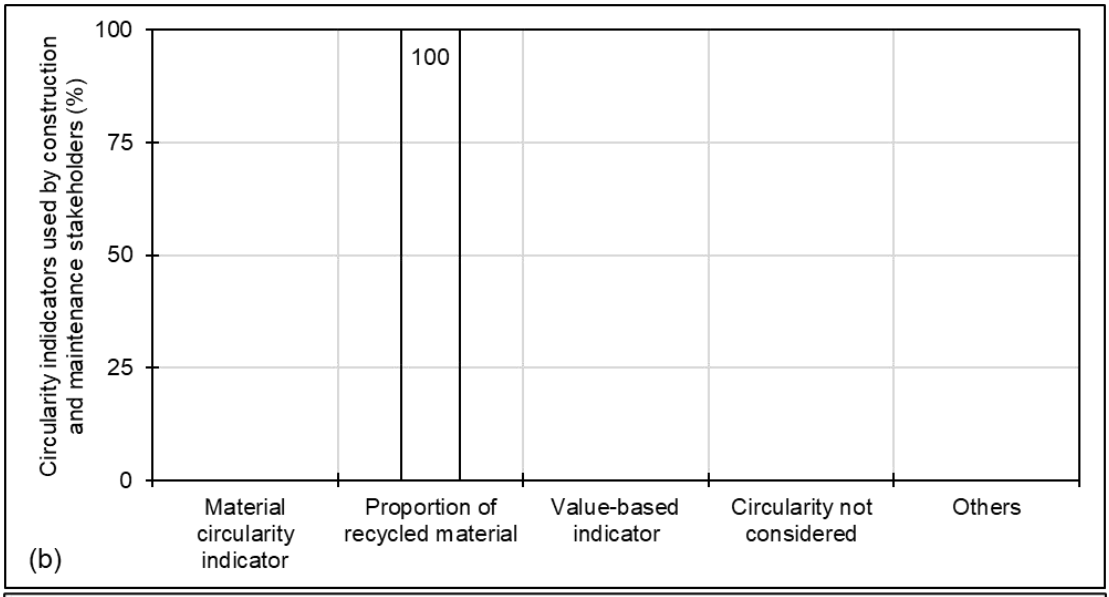


Figure 25. Indicators Used by the Roadway Construction and Maintenance Stakeholders: (a) Economic, (b) Circularity, and (c) Social

The different risk aspects considered by the NRAs while performing a pavement construction or maintenance activity are presented in Figure 26. It is important to mention that the collision and failure costs can be covered under economic performance with the help of indicators such as net present value and equivalent uniform annual costs. Further, the safety aspects can be presented through social impact assessment.

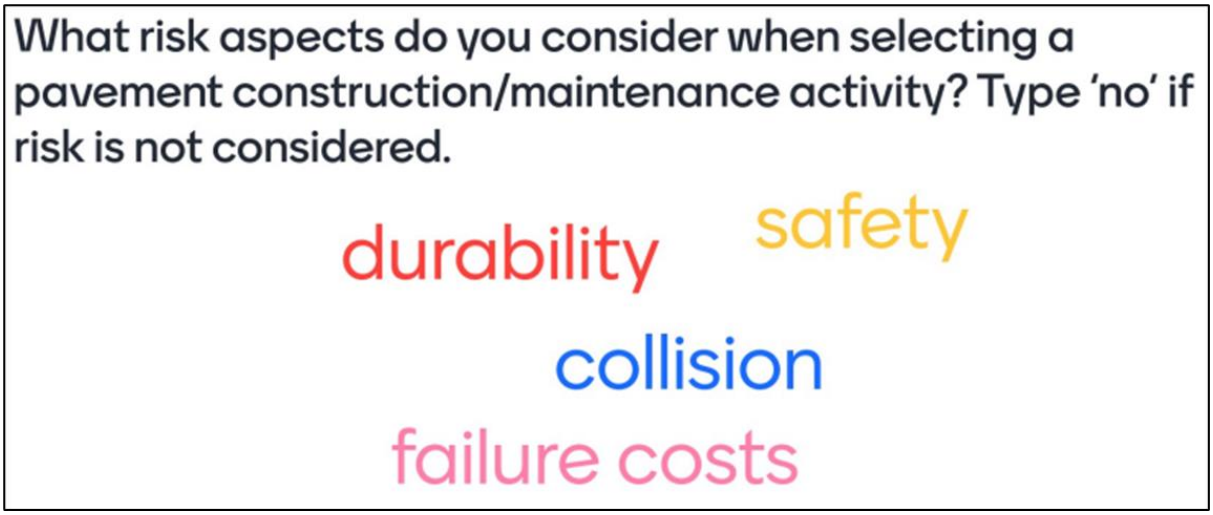


Figure 26. Risk Aspects Considered by the Roadway Agencies during Pavement Lifecycle

The information recorded by pavement construction and maintenance stakeholders during the service life of a pavement is presented in Figure 27. While majority of the road construction and maintenance stakeholders record the material types and flows, relatively less consideration is given to the energy consumption and waste generation during the lifecycle. Surprisingly, no interest was shown to record the durability aspects (e.g. skid resistance and ravelling with respect to time) and traffic characteristics such as flow, density, and vehicular distribution. Note that these aspects are essential to quantify the progressive failure in pavements, which governs the frequency and type of maintenance activities as well as the waste flows during the pavement's lifecycle.

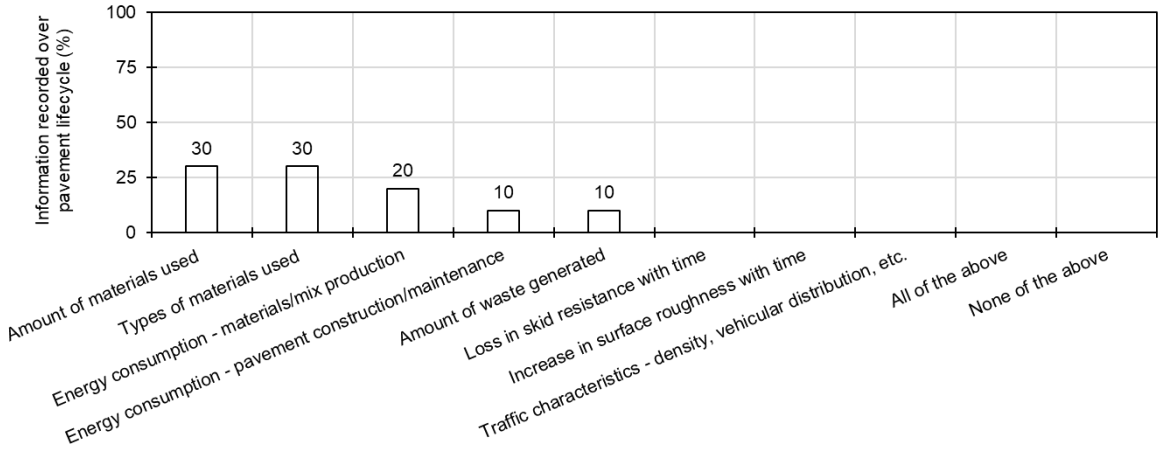


Figure 27. Data Collected during Lifecycle of a Pavement by the NRAs

4.2.6 Benefits and implications of integrating the RBAF in bidding

As part of the CERCOM project, a roadmap for integration of the RBAF within procurement practices was also proposed. The workshops provided an excellent opportunity to gain feedback on the proposed implementation from various contractors. A schematic illustrating the potential implementation strategy was presented. As part of the workshops, it was imperative to gain as much insight as possible from contractors into the potential barriers to implementation of the RBAF in current procurement processes. The attendees were invited to rank proposed potential barriers and the results are illustrated in Figure 28. The following options were provided for ranking:

- Time/resource constraints
- Inexperience of NRAs with RBAF
- Lack of data
- Sensitivity of data
- Standards
- Other

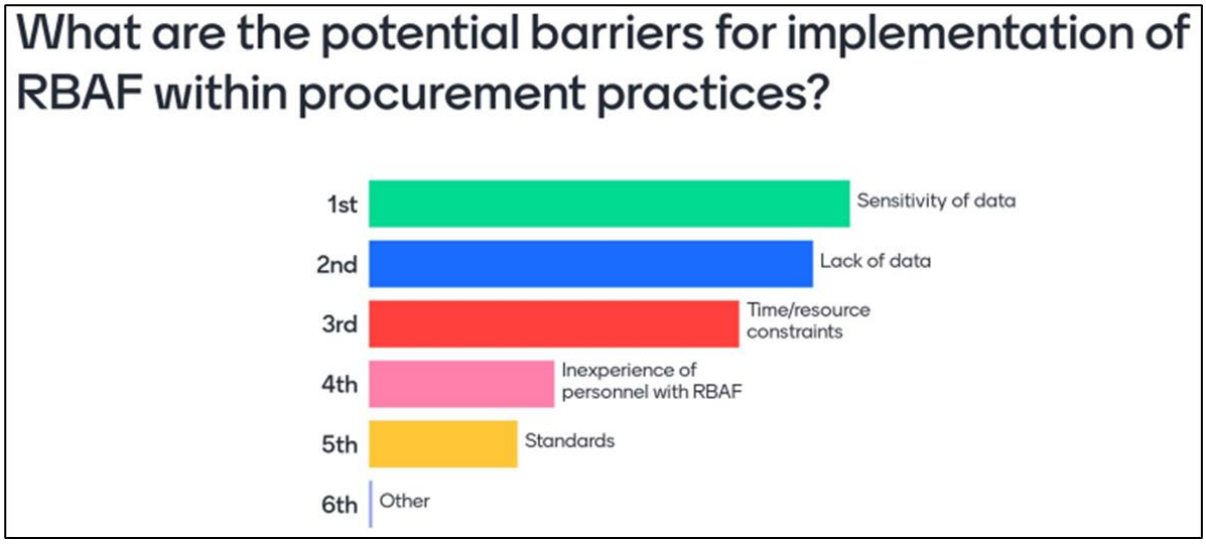


Figure 28. Barriers for Implementation of RBAF within Current Procurement Practices

The variation in feedback from contractors and NRAs highlights the distinction between obstacles faced by both stakeholders. Sensitivity of data was ranked as the biggest barrier for contractors, as they are likely concerned about protecting business interests regarding emerging innovative materials and approaches. It is anticipated that when more training and resources are provided and experience is gained in the use of the software tool, users will see the benefits of using the software in-house. Then, when used as part of the procurement process, it will be clear that only limited information will be required in tender submissions.

The feedback also highlights the importance of collating sufficient quality data to provide a robust means to generate KPI values to be integrated within the RBAF. Regarding time/resource constraints and inexperience of personnel with use of the RBAF, it is anticipated that the resource pack developed as part of Work Package 5 will provide sufficient materials to overcome these barriers. It will provide resources in different formats, demonstrating the user-friendly methodology that was adopted when developing the software tool. It is recognised that time and resources for training are limited, so the developed content will be concise and intuitive to reduce the resource demands, and increase confidence to overcome the barriers for implementation. The training resources will clearly outline how the software tool works, what inputs are required by the user and provide transparency on how the optimisation

is carried out. As datasets grow, standard threshold values should be identified for various criteria to ensure consistency in assigning KPI values for each option. To ensure a robust tendering process, it is envisaged that this data, along with weights assigned to each criterion would be outlined in the tender documents and specifications.

The feedback indicates that restrictions within standard is not considered a significant barrier for implementation. From various discussions throughout the CERCOM project, it is evident that functional specifications are being adopted in some countries and standards are being amended to allow for the integration of more circular solutions. It is likely that advances have already been made in this regard in the countries of participating contractors.

The participants were also asked to provide opinions on factors that would increase the motivation to consider CE and RE while submitting tender bids. The feedback is presented in Figure 29. The proposed factors were:

- Net zero targets (within organisation)
- Economic considerations
- Requirements in standards
- Specified in tender award criteria
- Availability of material
- Other

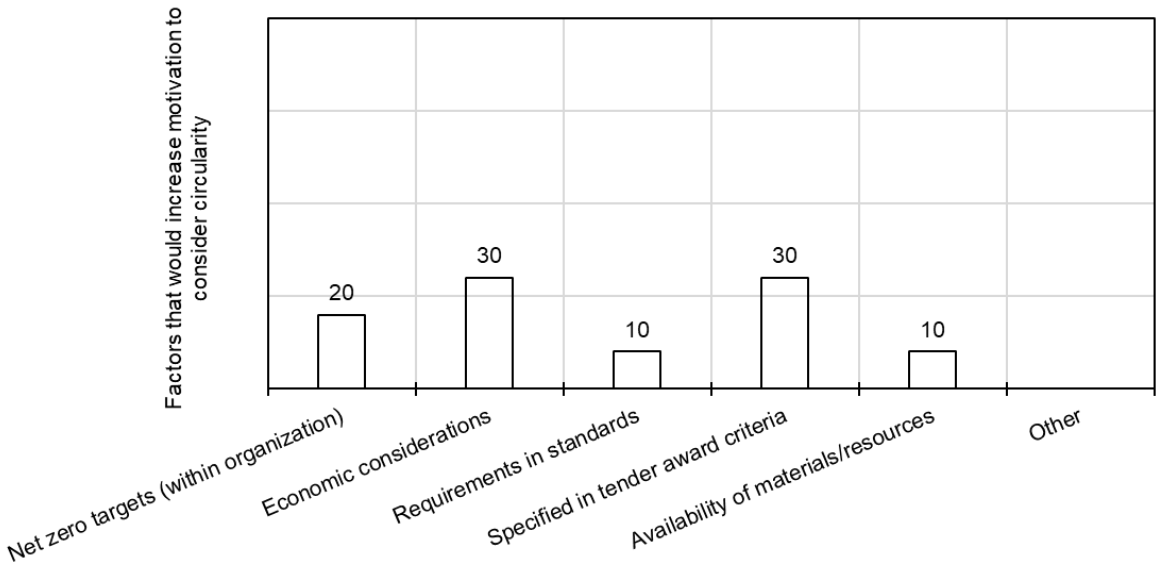


Figure 29. Factors that Promote Consideration of CE and RE during Tender Submission

All factors suggested were selected by one or multiple participants (with “other” being the only option not selected). Economic considerations and specifications within tender award criteria are the main motivating factors for the contractors participating in the workshop. It is likely that the increased cost of fuel, manufacturing/processing is having an impact on economic motivations. It is encouraging to see procurement procedures and tender award criteria ranked as high motivating factors. However, it is noted that contractor attendance at the workshop was modest, and likely doesn’t represent all contractors across countries participating in CERCOM. Net zero targets, availability of materials and requirements in standards were also selected as motivating factors. Within the factors considered, it is likely that standards and tender award criteria can be driven by NRAs and encouraged by modifying current practices and procedures in this regard. As discussed, it is likely that in many countries, that the collation of more robust quality data will be required to enable this progression to take place.

5 Lessons learned and recommendations

5.1 CERCOM maturity matrix

- The most common approach to implementing CE principles reported by workshop participants was establishing net-zero targets. A smaller number of participants reported having a circularity policy or procurement policy that includes CE criteria. No participants indicated that their organisations had definitions of CE, KPIs, business models or tools for assessing CE and RE in place.
- An appetite exists for a consistent approach for assessing progress in circularity and 85% of respondents indicated that the CERCOM maturity assessment matrix could be suitable for this, either with some changes or in its current form.
- It is recommended that WP5 develop suitable resources to support NRAs in applying the CERCOM maturity assessment matrix.

5.2 Development to promote circularity in road construction and maintenance

- All the examples presented from deliverable D4.3, of initiatives occurring to promote more circular practices were of significant interest to participants plus some other relevant examples were suggested.
- The responses given varied considerably – each initiative presented was thought to be of significant interest by at least one participant, while other participants had only a moderate interest, or no interest, in the same initiative. This presumably reflects the different situations for different NRAs. It confirms that establishing a varied 'toolbox' of different approaches and sharing experience of the variety of approaches being adopted will be valuable. The resource pack developed in WP5 should include or point to this information.

5.3 Risk-based analysis framework (RBAF)

- Although the results show variability in responses, feedback indicates that technical performance, economic performance and environmental impacts are currently ranked most highly when assessing tender documents.
- The development of software tools utilised by NRAs and contractors when assessing tender bids (e.g., DuboCalc and TII Carbon Tool) indicates the growing emphasis that is being placed on sustainability and environmental factors within the procurement process.
- Despite a wide spread of answers, the feedback from all workshops on the format of RBAF training resources suggests that all formats suggested would prove useful, with a video demonstration of the software ranked as most beneficial.
- The feedback shows some potential use of the RBAF within procurement procedures currently, with a significantly higher potential for implementation in the future. It is anticipated that this would increase further following with the availability of various training resources.

5.4 CERCOM case studies – Validation of RBAF

- Based on the feedback, it was understood that the NRAs have already started keeping records of the data relevant to both use and end-of-life phases. However, most of the contractors are still driven by the concept of sustainability and fail to keep a track from circularity perspectives. Some others focus only on the initial construction phase, which highlights the lack of understanding towards the integration of use and end-of-life phases for development of circular and sustainable roadway systems.
- Although the stakeholders are keeping a record of important technical performance indicators such as skid resistance, roughness, noise, and ageing resistance, another aspect that is worth monitoring includes deflection as it has substantial contribution to the overall impacts during a pavement's service life.
- Benefit-cost ratio is being used a common indicator by the NRAs and contractors to conduct the economic lifecycle assessment as it allows for easy comparison between the alternatives based on a ratio. Few NRAs resort to using net present value and several others rely on initial construction cost. Although initial construction cost is useful from budgetary requirements, it fails to provide an economic value over the complete lifecycle of a pavement, unlike net present value.
- Both the NRAs and contractors assess the CE and RE based on proportion of recycled materials. Note that recycling and reuse cover only two circularity aspects and there are several other strategies such as life extension that have potentially higher circularity benefits.
- Most of the NRAs do not consider social lifecycle assessment during tendering process either due to lack of expertise or unavailability of systematic quantification methods. However, the contractors were found to consider social aspects such as safety of workers and gender equality. Although these are two important indicators, there are several others (as detailed in CERCOM Deliverables 4.1 and 4.2) that must be incorporated into the assessment for rational understanding of the social impacts.
- In general, risk associated with a given pavement construction/maintenance project is either not considered or expressed in terms of cost and release of harmful elements into the environment (such as microplastics). Although some NRAs indicated considering the risks associated with pavement performance characteristics, there is lack of time-dependent prediction models, harmonized datasets, and tools that allow for rational quantification of the risk.
- Almost all the NRAs and contractors are recording the type of materials used and their proportion during pavement construction and maintenance. In addition, the variations in technical performance (e.g. skid resistance and ravelling) and traffic characteristics are also recorded by the NRAs, while the contractors do not evaluate these aspects.
- In order to promote circularity and sustainability, it is imperative for both NRAs and road construction and maintenance stakeholders to keep a record of pavement performance (e.g. durability of asset with passage of time), develop material passports, track unit processes in a system, and understand the significance of KPIs in evaluating a project.

5.5 Integration of the RBAF within procurement practices

- Participants from NRAs provided feedback indicating the most critical barriers for implementation are time/resource constraints, inexperience using the tool and lack of data.

- However, sensitivity of data was ranked as the greatest barrier for contractors, as they are likely concerned about protecting business interests regarding emerging innovative materials and approaches.
- The feedback also highlights the importance of collating sufficient quality data to provide a robust means to generate KPI values to be integrated within the RBAF, along with standardisation regarding CE indicators.
- It is clear from feedback the importance of developing various training materials that are concise and user-friendly to reduce the barrier associated with competence and transparency relating to the use of the RBAF software tool.
- Feedback from contractors participating in the workshop suggests that economic considerations and specifications within tender award criteria are the main motivating factors for considering circularity in tender bid submissions.

5.6 Developing tender specifications to facilitate circularity and resource efficiency

- Feedback from a large majority of NRA participants indicates that procurement policy is already being influenced by net zero / resource efficiency / circular economy. This appears to be occurring in two main areas: accounting for impacts – primarily carbon but with some consideration of wider environmental impacts and optimising the value delivered in each lifecycle through improving durability or applying whole life costing.

5.7 Contents of the resource pack to support circular procurement

- In addition to the recommendations noted above, the following areas were identified by participants as important topics to include in the resource pack developed in WP5:
    - Definition of RE and CE; benefits of a circular approach (e.g. in reducing carbon plus wider sustainability benefits)
    - Sources of reliable data
    - RBAF user manual; making this very technical topic easy-to-understand
- Different formats of content were preferred by different participants, so the resource pack should accommodate different types of material to suit differing learning styles.

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