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The Transition to Circular Economy in Transport Infrastructure - CERCOM and LIAISON Progression

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Abstract. To achieve climate neutrality, synergies between circular economy (CE) and carbon reduction need to be established in the context of transport infrastructure. Implementation of the circular economy and resource efficiency (RE) policies have the potential to facilitate decarbonization targets, while using fewer natural resources, maintaining or enhancing biodiversity and providing regenerative design for generations to come. This paper presents the interpretation of RE and CE within transport infrastructure in the context of the CERCOM and LIAISON projects. As part of CERCOM, a strategic review of current practice was carried out to develop a definition of CE within transport infrastructure, and provide the successes and barriers for further transition from a linear to a circular economy. A Risk Based Assessment Framework (RBAF) and associated software tool were developed to provide a means to evaluate the impacts of certain measures and prioritize areas that require further research or investigation. LIAISON will provide further progression in this regard, and develop a methodology, support tools and close to market technological solutions to transform EU Transport Infrastructure into a more sustainable and low carbon economic activity.

Keywords: Circular Economy · Resource Efficiency · Transport Infrastructure · Risk Assessment · Carbon Neutrality

1 Introduction

Urgent action is required by governments and organizations around the world to mitigate the effects of climate change and all sectors have a responsibility to reduce their climate impact. The transportation sector alone is responsible for approximately one fifth of global CO₂ emissions [1]. Whilst most of these emissions derive from the operation

of Transport Infrastructure (TI), construction and maintenance also have high environmental impacts and are responsible for significant material consumption and associated CO₂ emissions. To speed up the process for circular TI we need European cooperation to ensure alignment and coordination of policies, strategies, standards and procurement, while also encouraging data collection and knowledge sharing of innovations at EU scale.

Circular economy (CE) has the potential to further the process of decarbonization by transforming the way in which products are manufactured and used. The move away from a linear economy towards the adoption of resource efficiency (RE) and CE principles has the potential to reduce harmful emissions as well as preserve natural resources.

2 Circularity in Transport Infrastructure

To achieve a circular economy, change is required across Europe and beyond, since the supply of raw materials and waste flows are global. It is essential that the entire workforce embrace the change and knowledge, skills and mindset required to make a significant change in achieving decarbonization. Infrastructure management, policy makers, supply chain and delivery teams all need to take responsibility in evaluating options, developing solutions, generating procurement opportunities and delivering available solutions. Procurement policies by national TI administrations have a great influence on the supply chain. A review of circularity within national road authorities (NRAs) in Europe found that many NRAs were including CE principles without formally implementing CE policies or strategies [2]. For progress towards achieving emission reduction and circularity in TI, it is essential that road and rail administrations support evidence gathering, data collection, identification and sharing of successful implementation and lessons learned.

Research Driven Solutions (RDS) were coordinators of CERCOM, which developed tools and frameworks to facilitate the adoption of CE and RE principles in procurement by NRAs across Europe [3]. The project was commissioned as part of Conference of European Directors of Roads (CEDR) Transnational Research Call of 2020 [4]. During the two-year project, various technical, operational, procurement opportunities and barriers were examined in the move towards more circular practices. One of the outcomes was the delivery of an innovative risk-based framework and management tool to facilitate a step change in the adoption of resource efficiency and circular economy principles in procurement and multi-lifecycle management by NRAs. The use of the tool was demonstrated through the analysis of various case studies related to construction and maintenance activities within the road sector.

RDS are currently partners on LIAISON, which will further enhance progress made within previous projects and will develop a methodology, support tools and close to market technological solutions to transform EU Transport Infrastructure into a more sustainable and low carbon economic activity [5]. A governance framework will be developed to demonstrate the benefits of these innovations to end-users, which will rank various infrastructure construction and maintenance solutions not only in terms of circularity, but also in terms of essential characteristics of construction works, safety, health, environment, resilience and costs.

3 CERCOM Risk Based Assessment Framework (RBAF)

A key deliverable of the CERCOM project was a risk based framework and software tool to facilitate circular procurement while assessing the technical risk of incorporating novel or innovative solutions into design, maintenance and construction of road infrastructure. The goal was to provide a means to assess current practice and the potential benefits of more circular solutions in increasing resource efficiency, minimizing waste and reducing the use of virgin materials. However, when considering procurement, it is necessary to also consider more traditional criteria such as Performance, Cost, Environmental and Social factors. As such, the Risk Based Assessment Framework (RBAF) was developed to take account of all these factors. There are 5 steps within the risk assessment framework (Fig. 1):

- Establish context - Includes the primary goals of the assessment, the hazards involved, the potential actions to reduce risk, the consequences to be considered and how the hazards and consequences will be calculated, identifying the specific spatial and temporal boundaries of the assessment in question
- Evaluate likelihoods - Includes details on likelihood of a “failure” event (P_f) or the probability of exceedance of a given damage state for given scenarios of hazard and action
- Evaluate consequences – Includes direct and/or indirect consequences/costs associated a with failure event
- Establish additional KPIs – Involves quantification of RE&CE, Cost, Environment and Social Key Performance Indicators (KPIs)
- Optimize – Involves optimization of various assessment criteria and KPIs

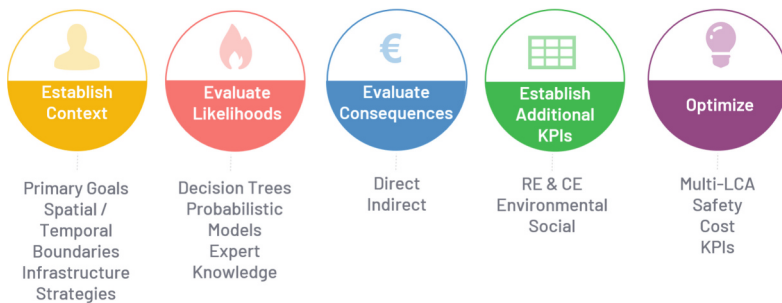


Fig. 1. CERCOM Risk-Based Analysis Framework

For each potential construction or maintenance option, the risk associated with this strategy is calculated ($\text{Risk} = P_f \times \text{Consequences of failure event}$). Within the RBAF, consequences are taken as the costs associated with a failure event (e.g., the direct and/or indirect costs associated with emergency resurfacing due to premature loss of skid resistance).

As part of the tool, single or multiple KPIs can be defined and integrated under the categories Performance, Cost, Circular Economy, Environmental and Social. The

developed KPIs ensure that contractors can be rewarded for producing a scheme that will be long lasting, cost effective to maintain, use limited amounts of raw materials, designed for multiple lifecycles and/or can be readily repaired for (multi) life extension. A system of ranked interpolation is used to quantify KPIs. The first rank for each KPI is assigned a value of 0.0, and the final rank is assigned a value of 1.0. In the simplest case, a linear relationship is assumed between the first and final rank. Where a more complex response is required, a multi-linear or quadratic relationship may be determined between different KPI ranks. Ideally, KPIs should relate to existing targets and practices already defined by the overseeing NRA. For example, an NRA with a target to use more recycled content in maintenance schemes may already define different “levels” or ranks of achievement of this goal. These “levels” can be related to KPI values and ranks for quantifying KPIs for potential schemes, and an example is outlined in Table 1.

Table 1. Example KPI ranks for recycled content.

Rank	KPI Value	Description	Recycled Content Example
1	0	No commitment to KPI ambition	No recycled content
2	0.1	Below minimum industry practice	5% recycled content
3	0.25	Minimum industry practice	10% recycled content
4	0.5	Exceed industry practice	40% recycled content
5	0.75	Far-exceeds industry practice	70% recycled content
6	1	KPI ambition achieved	100% recycled content

Within the developed software tool, these factors are combined into a single metric, a weighted sum giving the user a clear indication of the optimal solution from a range of potential options. As with any tender evaluation, weight factors are used to quantify priorities of each NRA for a specific project/scheme.

The developed tool provides sufficient flexibility to allow NRAs to decide on the level of engagement with the CE process, based on current CE maturity as well as future needs. Within the developed framework and software tool, the functionality and capabilities can be adapted to suit the maturity of NRAs at any given time and can also be tailored to suit the scope and type of scheme under consideration. As such, it will prove to be a valuable tool in the move towards a circular approach in the procurement process of construction and maintenance of road infrastructure.

4 Results and Outcomes

The developed CERCOM Software Tool provides a versatile means for NRAs to assess the risk of using innovative circular construction and maintenance methods and materials along with additional criteria to facilitate optimum selection of scheme options and associated procurement practices.

The framework and software were updated and refined based on the practical experience gained from analyzing various case studies within the final months of the project.

This provided an opportunity to validate and demonstrate the framework within the scope of the CERCOM project. As such, it will prove to be a valuable tool in the move towards a circular approach in the procurement process of construction and maintenance of road infrastructure.

There is flexibility to include output results from independent Life Cycle Analysis (LCA) and Life Cycle Cost Analysis (LCCA) into the developed software tool to provide additional functionality and complexity. The fundamental limitation associated with the software tool is the availability of reliable data to assign values for criteria associated with alternative maintenance strategies and data to define thresholds for ranked interpolation.

Various training resources developed as part of CERCOM are provided on the project website and can be used to implement the necessary changes towards the adoption of circular economy practices in road construction and maintenance [3]. The resource pack content was tailored to reflect feedback received within various stakeholder workshops. The resources are divided into sections, offering materials with varying complexity, format and length to accommodate NRAs at different stages on the road to circularity.

5 Future Developments

LIAISON will further progress on advances made in previous research projects in the area of circularity and carbon reduction in TI by focusing on the implementation within four main areas:

1. Minimizing the consumption of resources
2. Reusing available resources
3. Evolving towards a prosumer infrastructure
4. Actions to facilitate market uptake by supporting procurement, legislation and standardisation processes

Research has shown that the implementation of innovative circular demonstration pilots has the greatest potential to increase the pace of circularity uptake within public procurement of infrastructure solutions [6]. On this basis, LIAISON will demonstrate a developed methodology using a set of representative and complementary use cases across Europe, comprising of industrialized solutions, circular solutions and smart operation and maintenance solutions.

The methodology will consider a whole life cycle perspective, from conception and design through generative and sustainable performance-based operation and maintenance stages, up to the decommissioning phase. To demonstrate the benefits of these innovations to end-users, a Dynamic Multi-Infrastructure Governance Framework (DMIGF) will be developed to rank various infrastructure construction and maintenance solutions not only in terms of circularity, but also in terms of essential characteristics of construction works, safety, health, environment, resilience and costs. It is essential that decisions are based upon a single framework where each of these indicators can be prioritized together.

This governance framework will act as a system of sustainability principles, procedures, indicators and accountabilities used by TI stakeholders to ensure a transparent measurement of transport infrastructure impacts throughout its full life cycle, and to keep

the safety / performance / cost / zero-emissions targets of the sector optimally balanced. The work will build on the CERCOM RBAF, providing additional progression in the following areas:

- fostering the uptake of the framework across all transport modes
- facilitating significantly more advanced risk-based analysis incorporating structural health monitoring data, uncertainty modelling etc.
- demonstrating and validating the methodology with various new and innovative technologies delivered within LIAISON

It is envisaged that to encourage its adoption, the DMIGF should be prescribed by administrations and TI investors through standards and procurement procedures. This will facilitate the generation of good practices going forward (e.g., setting circularity KPIs targets for TI at network and asset level, for different modes, at different lifecycle stages). Specific actions will be implemented by LIAISON to address these needs, including specific activities towards policy guidelines, standardisation and public procurement guidelines to aid adoption of circularity criteria in TI projects.

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