



LIAISON DMIGF Methodology – Initial version

D1.1: Digital Dynamic Multi-Infrastructure Governance framework for TI

Authors: Emma Sheils (RDS); Lorcan Connolly (RDS) Beatriz Mateo Sanz (CEDEX), Joaquim Tinoco (UMINHO); Elisabete Teixeira (UMINHO); Antonia Perez Hernando (UC)



Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Technical references

Project Acronym	LIAISON
Project Title	Lowering transport environmental Impact along the whole life cycle of the future tranSpOrt iNfrastructure
Project Coordinator	David Garcia Sanchez TECNALIA david.garciasanchez@tecnalia.com
Project Duration	May 2023 – April 2026 (36 months)
Deliverable No.	D1.1
Dissemination level*	Public
Work Package	WP 1 – Digital Dynamic Multi-Infrastructure Governance Framework for TI
Task	T1.1 – Current and Future Circularity in Transport Infrastructure T1.2 – LIAISON Dynamic Multi-Infrastructure Governance Framework (DMIGF)
Lead beneficiary	Research Driven Solutions (RDS)
Contributing beneficiary/ies	Universidad de Cantabria (UC), Universidade do Minho (UMINHO), Centro de Estudios y Experimentación de Obras Publicas (CEDEX)
Due date of deliverable	31 July 2024
Actual submission date	31 October 2024

* PU = Public

SEN = Sensitive



LIAISON DMIGF Methodology – Initial version

v	Date	Beneficiary	Author
0.1	14/07/2023	RDS	Emma Sheils
0.2	06/11/2023	CEDEX	Beatriz Mateo Sanz
0.3	13/11/2023	UMINHO	Joaquim Tinoco , Elisabete Teixeira
0.4	29/02/2024	UMINHO	Elisabete Teixeira
1.0	22/07/2024	RDS	Lorcan Connolly
1.1	23/09/2024	ICONS	Alice di Ferrari
1.2	23/09/2024	ACC	Laura Piarulli, Rafael Ruiz
1.3	07/10/2024	CEDEX, UC	Beatriz Mateo Sanz, Inmaculada Robles, Andres Ortega; Antonia Perez Hernando
1.4	17/10/2024	TEC	Maria Zalbide, David Garcia Sanchez
2.0	18/10/2024	RDS	Lorcan Connolly



Table of contents

Technical references	2
Table of contents	4
1.1. List of Tables	5
1.2. List of Figures.....	6
1. Introduction	8
1.1. Project and Deliverable Introduction	8
1.2. Deliverable Structure	8
2. Understanding Circularity in the Transport Sector in Europe	11
2.1. Assessing progress and barriers towards circular economy	11
2.1.1. Introduction.....	11
2.1.2. European and National policy, economy and strategy	13
2.1.3. Barriers.....	19
2.2. Definition of circularity in the context of transport infrastructure	22
2.2.1. Introduction.....	22
2.2.2. Definition of circularity for LIAISON project	25
3. Current HE projects: Circuit	26
4. International lookout and trends in circular uptake	27
4.1. Implementation strategies adopted by Transport Administrations	27
4.2. International practice and case studies	32
4.2.1. Examples from the Road Sector.....	32
4.2.2. Examples from the rail sector	35
4.2.3. Increase in the recycling of construction waste	36
4.2.4. Application of sustainable alternatives	37
4.2.5. Smart systems and operation of TI.....	38
4.2.6. Research and innovation.....	39
4.3. Performance measurement / KPIs	40
4.4. Review of European standards and trends in circularity.....	45
4.4.1. PAS 2080:2023 Carbon management in buildings and infrastructure	45
4.4.2. UK Design Manual for Roads and Bridges.....	46
4.4.3. Irish National standards.....	46
4.4.4. Spanish National standards.....	47
4.4.5. Portugal - National Laboratory of Civil Engineering (LNEC) specifications...47	
4.4.6. Recommendations	48
4.5. Procurement and supply chain	48
4.5.1. Sustainable public procurement (SPP).....	49
4.5.2. Green public procurement (GPP)	50
4.5.3. Circular public procurement (CPP).....	51
4.5.4. National examples.....	51



5. Identification of the economic, regulatory and incentivization framework55

5.1. Organizational culture.....	55
5.1.1. Standards related to organizational culture	55
5.1.2. Platform CB'23	56
5.1.3. CinderOSS	56
5.1.4. CERCOM maturity model.....	57
5.2. Regulatory and incentivization frameworks to foster circularity in TI.....	58
5.2.1. Impact of regulatory frameworks	58
5.2.2. Additional economic incentives	59
5.3. Business case for implementation	60
5.4. Summary of good practice	61

6. DMIGF Proposal and Discussion.....63

6.1. Introduction.....	63
6.2. Alignment with Level(s) approach	63
6.3. Risk-based methodology	65
6.4. Additional indicators	68
6.4.1. Life Cycle Assessment (LCA).....	69
6.5. Uncertainty.....	72
6.6. Normalization of indicators	73
6.7. DMIGF process	75
6.8. Indicative examples (with virtual data).....	78
6.8.1. Risk / Technical performance	78
6.8.2. Environmental category – Carbon emissions	82
6.8.3. Sample DMIGF output.....	83
6.9. Demonstration pilot.....	85
6.9.1. Methodology proposed	85
6.9.2. Indicators definition	86
6.9.3. Sample Indicators for the installation of bioasphalt	87
6.9.4. Demonstration Pilot Indicators. A-67 Project	95
6.9.5. Indicators in tender documents	96
6.10. Roadmap to implementation	98
6.11. Conclusion	101

7. Deliverable Summary102

Annex I.....103

1.1. List of Tables

Table 1 Adherence to LIAISON GA Deliverable & Task Descriptions.....	8
Table 2 Examples of the interpretation of circularity	24
Table 3 Advances of CE and case studies in the road sector	33
Table 4 Circularity indicators reviewed as part of CERCOM project	41



Table 5 Example of CE and environmental indicators currently used within TI.....	42
Table 6 Outline of Level(s) macro-objectives and indicators.....	44
Table 7 Indicators Definition	87
Table 8 Work Unit Indicators. Installation of Bioasphalt.....	94
Table 9 Demonstration pilot Indicators. A-67	95

1.2. List of Figures

Figure 1 Global GHG emissions, 2010 (billion tons of CO ₂ e per year), reproduced from Ellen McArthur Foundation	12
Figure 2 Tackle carbon early – carbon reduction curve. Reproduced from Green Construction Board 2013.	13
Figure 3 Overview of European Nation Net-zero targets (data from NetZeroTracker, August 2023)	14
Figure 4 9 'Rs of the Circular Economy (reproduced from Kirchherr et al.).....	23
Figure 5 Life cycle carbon emissions associated with various forms of road pavement construction. Reproduced from Decarbon8 report.....	36
Figure 6 Relationship between Level(s) macro-objectives and DMIGF categories.....	64
Figure 7 Relationship between Level(s) approach and LIAISON Demo Cases	65
Figure 8 Proposed DMIGF risk-based methodology.....	66
Figure 9 Stochastic modelling of performance to calculate likelihood of inadequate performance	67
Figure 10 Qualitative matrix-based approach to evaluate likelihood of inadequate performance	67
Figure 11 Qualitative matrix-based approach to evaluate risk	68
Figure 12 Sample indicators under each category.....	69
Figure 13 Life Cycle Assessment Methodology	70
Figure 14 Transportation Infrastructure Life Cycle Phases	71
Figure 15 Stochastic modelling to evaluate uncertainty	72
Figure 16 Qualitative approach to evaluate uncertainty based on 4 criteria headings	73
Figure 17 Qualitative matrix-based approach to evaluate uncertainty	73
Figure 18 Ranked interpolation approach	74
Figure 19 DMIGF for aggregated KPI metric for each category	76
Figure 20 Incorporation of LCA into DMIGF (a) time dependent approach (b) cumulative value over reference period	78
Figure 21 Quantitative approach to determine likelihood of inadequate performance	80
Figure 22 Indicative example – calculation of risk and associated uncertainty.	80
Figure 23 Indicative example – qualitative approach to determine risk and uncertainty	81
Figure 24 Comparison of potential quantitative and qualitative approaches	82
Figure 25 Determination of uncertainty for carbon emissions example	83
Figure 26 DMIGF prospective results format	84
Figure 27 Work Unit expressed in indicators	85
Figure 28 RECIPE Indicators EU	86
Figure 29 PEF Indicators Netherlands	86
Figure 30 Components Environmental Toxicity. Source RECIPE and PEF.....	87
Figure 31 Cost Data of Work Unit	88



Figure 32 Risks Data of Work Unit to Risks Indicators.....	89
Figure 33 Environmental Data of Work Unit to Environmental Indicators	90
Figure 34 RE&CE Data of Work Unit to RE&CE Indicators	91
Figure 35 Social Data of Work Unit to Social Indicators.....	92
Figure 36 Cost Data of Work Unit to Cost Indicators	93
Figure 37 Roadmap to implementation.....	100



1. Introduction

1.1. Project and Deliverable Introduction

LIAISON aims to provide knowledge and technical solutions to reduce emissions arising from transport infrastructure (TI). The project will investigate smart and sustainable beams, rigid road pavements and improved ballast; bioasphalts and smart pavement inspection systems; intelligent tunnel control systems and photovoltaic guardrails. LIAISON covers the whole life cycle of TI, providing a means to limit the overall emissions from construction, maintenance, operation and decommissioning of the infrastructure.

The LIAISON **Dynamic Multi-Infrastructure Governance Framework (DMIGF)** is a methodology to facilitate the transformation of EU Transport Infrastructure into a more circular and low carbon economic activity. Within LIAISON, the methodology will be validated with the demonstration pilots mentioned above, and will be used to demonstrate the value of each approach. The report is Deliverable 1.1 of the LIAISON project – DMIGF Methodology – Initial Version. It will detail the preliminary analysis which defined the DMIGF format, before describing the current DMIGF and demonstrating its application for one demo case. The final version of the DMIGF will be delivered in month 36 of the project as part of Deliverable 1.4, after application to the LIAISON demo cases.

Unlike recent projects developed in Europe, LIAISON has a clear vision of implementation and both the definition and selection of indicators as well as their measurement and analysis have been contrasted all with main actors in the construction sector, world leading software developers and Public Administrations. This deliverable describes the elements that should be considered for a real procurement implementation process according to the life cycle of the infrastructure: Project Drafting Tender (see Annex I), Construction Tender, Technical Assistance Tender and Maintenance Tender.

1.2. Deliverable Structure

This report details the outputs of Tasks 1.1 and 1.2 of the LIAISON project, as per the LIAISON Grant Agreement (GA). The adherence to the GA is provided in Table 1 below.

Table 1 Adherence to LIAISON GA Deliverable & Task Descriptions

LIAISON GA Component Title	LIAISON GA Component Outline	Document Chapter	Justification
D1.1: LIAISON DMIGF Methodology – Initial version	- Definition of the LIAISON methodology to foster the circularity of TI, as result of Task 1.1 and Task 1.2. - Output will be a Guideline for implementation including risk	Chapter 5	Chapter E provides a detailed overview of the DMIGF, including risk assessment as



LIAISON GA Component Title	LIAISON GA Component Outline	Document Chapter	Justification
	assessment and the LCCA for circularity purpose.		well as LCA (Section E.4.1)
Subtask 1.1.1: Understanding circularity in the transportation sector in Europe	Review the current state of play in the circularity of transport infrastructure construction and maintenance throughout Europe.	Chapter 2	- B.1.1 introduces circularity in Europe. - B.1.2 provides the current state of play in various countries
Subtask 1.1.2 – International lookout and trends in Circularity uptake:	- Examine what circularity means in the transport sector today and identify the main barriers to circularity uptake across Europe. - A definition for circularity in the context of the LIAISON project will also be developed.	Chapter 2	- B.2.1 introduces circularity in TI in Europe. - B.1.3 addresses barriers. - B.2.2. provides the definition of circularity
Subtask 1.1.3 Identification of the economic, regulatory & incentivisation framework	- Identify Best practice from a technical perspective to foment the application of circular economy principles on an organisational basis. - Active economic incentives such as tax breaks and life cycle costing will be paired with best practice tools to develop a business case for implementation. - Review the impact of regulatory frameworks to foster circularity.	Chapter 3 & Chapter 4	- C.1 shows strategies implemented and C.2 outlines case studies. Best practice is shown in D.4. - D.2 shows incentives with regulatory frameworks and standards (C.4). Business case is shown in D.3.
Subtask 1.2.1 Risk Based Assessment Methodology	Develop a quantitative risk-based assessment methodology to evaluate the circular economy potential of transport infrastructure construction and maintenance strategies. This framework will include the definition of the circular performance indicators.	Chapter E	Based on Task 1, particularly KPIs (C.3), procurement (C.5) and organisational culture (D.1), the framework is described in Sections E.3-E.7
Subtask 1.2.2 Incorporation of Life Cycle	Develop and deliver the process required to integrate LCA into the risk-based analysis framework.	E.4.1	This sub chapter shows how LCA is included in the DMIGF



LIAISON GA Component Title	LIAISON GA Component Outline	Document Chapter	Justification
Analysis in Methodology			
Subtask 1.2.3 Guideline Detailing Roadmap to Implementation	• A roadmap to implementation will be defined as a function of TI manager maturity level. • The roadmap will define the data requirements and as a consequence, outline a basis for harmonised data sharing strategies.	6.10	The initial roadmap for application of the DMIGF is provided. This will be finalised in LIAISON D1.4



2. Understanding Circularity in the Transport Sector in Europe

2.1. Assessing progress and barriers towards circular economy

2.1.1. Introduction

Urgent action is required by governments around the world to mitigate the worst impacts of climate change and organizations across all sectors have a responsibility to reduce their climate impact. Transportation alone is responsible for around one fifth of global CO₂ emissions¹. Whilst most of these emissions derive from the operation of transport infrastructure (TI), construction and maintenance are also responsible for significant material consumption and associated CO₂ emissions.

To speed up the process for circular TI (carbon-neutral construction, maintenance, operation and decommissioning) we need European cooperation to ensure alignment and harmonization of protocols, norms and standards, while boosting knowledge generation and exchange of innovations at EU scale. TI is asking for a new way of doing business. jumping from traditional circular product development strategies to “product-as-a-service” circular concepts and business models that must coexist with a high government-driven sectoral structure.

It is well known that TI has a high environmental impact due to material use, waste production and CO₂ emissions (during construction and operation). With 136,700 Km of roads and 234,037 Km of railways, Europe has one of the largest TI networks in the world. Consequently, the European transport network has a very high environmental impact, in terms of:

- **Resource consumption:** TI networks are permanently upgraded, through the construction of new roads and railways (new corridors, elimination of high-risk sections, improvement of the capacity of critical sections, etc.), the adaptation of existing ones to comply with new regulations (security, safety, comfort, resilience, etc.), and through maintenance activities (pavement replacement, ballast maintenance, etc.) including provisions for various energy and natural resource demands. As a result, in the 27 EU member states in 2020, 600 M tons of aggregates, 43.7 M tons of cement, 208.3 M tons of asphalt, including around 6.0 M tons of bitumen, were used.
- **Energy consumption and GHG emissions:** the transportation sector is responsible for a third of the total final energy consumed and the CO₂ generated in the EU. Additionally, the operation of some elements of the TI network, such as road tunnels, lightning systems, etc., is responsible for heavy consumption of energy

¹ Richie, H (2020) Cars, planes, trains: where do CO₂ emissions from transport come from? <https://ourworldindata.org/co2-emissions-from-transport>, accessed 28/07/2023



- Economic impact: From now until 2040, approximately \$2 trillion in TI investments would be needed worldwide every year to adapt the TI to future needs.

It is essential that these impacts are reduced to achieve the European sustainability goals. However, TIs also have huge potential for resource generation. On one hand, much of the waste currently generated in TI interventions can be reused and recycled to create new construction materials and products. On the other hand, there is a huge unexploited potential to deploy renewable energy generation systems along with energy recovery and saving solutions.

To date, efforts to tackle climate change have focused on energy efficiency and the transition to renewable energy. The Ellen McArthur Foundation² recognizes that though crucial and generally consistent with a circular economy principles, these measures only address around 55% of emissions (Figure 1). The remaining 45% comes from the production of goods, food and land management. Circular Economy therefore 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 circular economy (CE) principles has the potential to reduce harmful emissions as well as preserve natural resources.

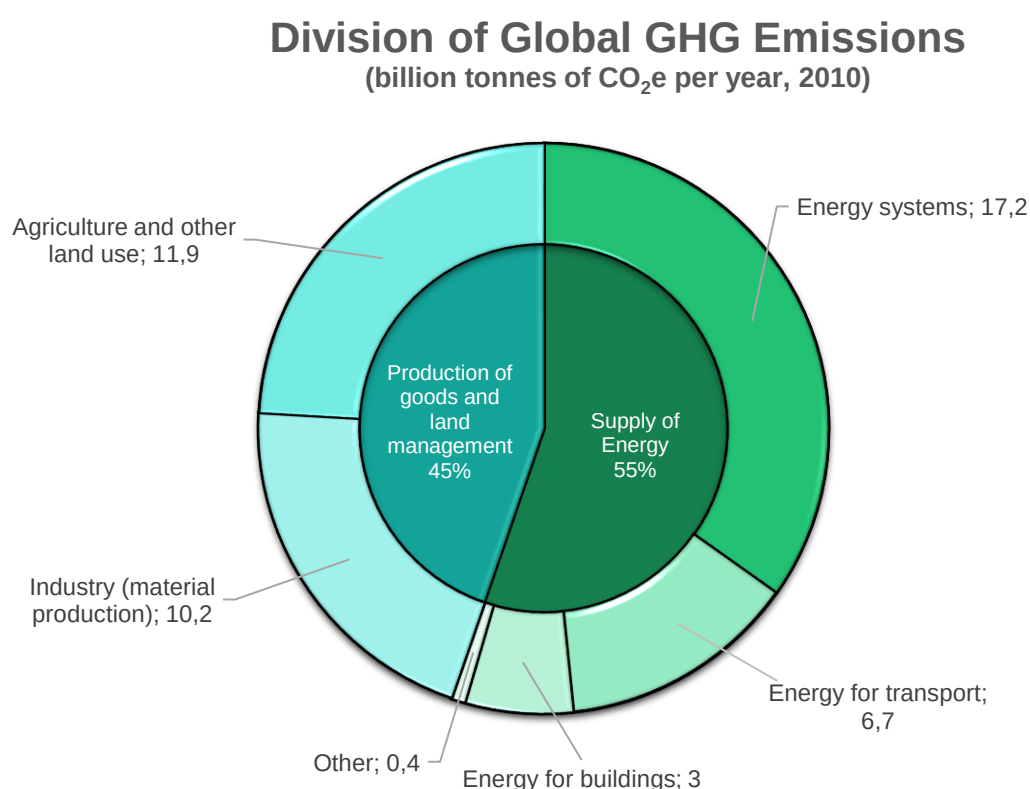


Figure 1 Global GHG emissions, 2010 (billion tons of CO₂e per year), reproduced from Ellen McArthur Foundation²

² Ellen McArthur Foundation, (2021), Completing the picture, how the circular economy tackles climate change.
<https://ellenmacarthurfoundation.org/completing-the-picture>



The impact of various measures regarding capital carbon reduction are illustrated in Figure 2. Carbon reduction can take place at any point in the delivery of a scheme, however, there is higher potential early on in the process. During development and scheme design, clients, consultants, designers and suppliers have the ability to reduce carbon up-front through fundamentally rethinking the business model, or by building more effectively and efficiently.

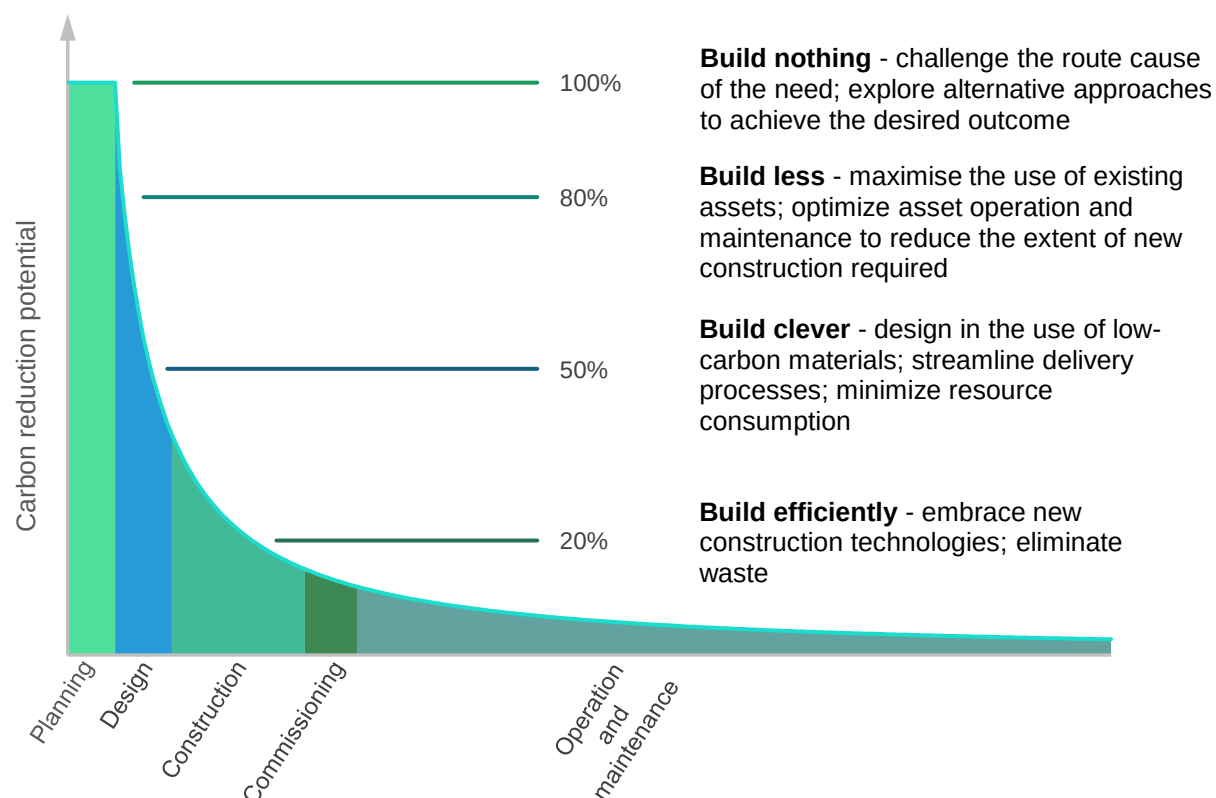


Figure 2 Tackle carbon early – carbon reduction curve. Reproduced from Green Construction Board 2013³.

2.1.2. European and National policy, economy and strategy

Many national governments across Europe have made strong commitments to reduce greenhouse gas emissions (GHG) to tackle the global climate crisis, and have defined policies and strategies with the goal of achieving Net-Zero.

For change to be implemented, a long-term strategy is essential with baseline levels established as well as intermediate and long-term targets for reducing carbon emissions. Most countries in Europe have set Net-Zero targets, with varying degrees of progress (e.g., in law, in policy document, pledged or proposed). Figure 3 provides a breakdown of progression in the 44 European nations⁴. Within this analysis, the following are examples of

³ Green Construction Board: Infrastructure Carbon Review Technical Report, 2013. ([Infrastructure-Carbon-Review-Technical-Report-25-11-13.pdf](https://www.constructionleadershipcouncil.co.uk/infrastructure-carbon-review-technical-report-25-11-13.pdf) ([constructionleadershipcouncil.co.uk](https://www.constructionleadershipcouncil.co.uk)))



terms that are considered as indicators of net-zero targets: Net-zero; zero emissions; zero carbon; climate neutral and carbon neutral. Emissions reduction targets (without a net-zero target) are categorized within the heading “No target” in Figure 3.

It is noted that although the language is sometimes used interchangeably, there is a distinction between Net-zero and carbon neutral. Net-zero carbon implies the reduction of carbon to as close to zero as possible. Residual emissions are then offset using carbon sinks. This can be done using natural carbon sinks like forests or using emerging carbon capture technologies. This differs slightly from carbon neutrality, where an independent operation of carbon offsetting takes place to balance carbon emissions.

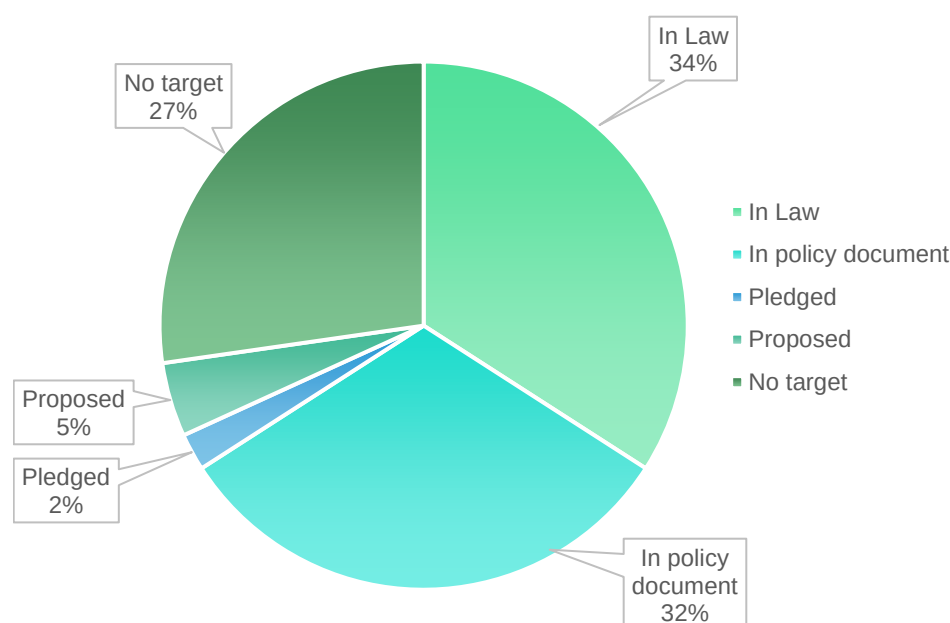


Figure 3 Overview of European Nation Net-zero targets (data from NetZeroTracker⁴, August 2023)

In 2016, at the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP22), the goal of achieving Carbon Neutrality by 2050 was set, contributing to the more ambitious objectives of the previous Paris Agreement. So, in 2019 the Roadmap to Carbon Neutrality 2050 (RNC2050) was created which set out the vision and trajectories for Portugal to achieve carbon neutrality by 2050⁵, i.e. to make the balance between emissions and removals of carbon dioxide and other greenhouse gases (GHGs) from the atmosphere.

COP26 took place in October/November 2021, where an entire day was dedicated to bringing together leaders from across the transport sector to accelerate the decarbonization of various transport modes. There was a strong focus on the transition to zero emission vehicles as part of the acceleration to zero emissions transport and the goal of keeping

⁴ [Net Zero Tracker | Welcome](#)

⁵ Tarrafa, L., Dias, Â., & Filipe, C. Roteiro Para A Neutralidade Carbónica 2050.



global warming under 1.5 degrees⁶. A declaration was signed by over 100 national governments to support accelerated transition to zero emissions vehicles, with the sale of internal combustion engines to stop by 2035 in leading markets⁷.

At COP27 in November 2022, unlike COP26, there wasn't an entire day dedicated to discussing the transport sector, despite it being one of the largest emitters of greenhouse gas emissions, contributing to 30% of global CO2 emissions⁸. As part of a session on Sustainable Transport, the focus was on the move towards electric vehicles, with little emphasis on other mechanisms to reduce emissions, such as modal shift and the increased use of public transport⁹. However, the LOTUS (Low Carbon Transport for Urban Sustainability) initiative was launched at COP27 with the aim of delivering the changes needed in the area of public transport, with a focus on increased investment in e-vehicles and driving systematic change to decarbonize public transport worldwide¹⁰.

COP28 took place in the United Arab Emirates (UAE) in November/December 2023, where a landmark deal, called the UAE Consensus, was approved to encourage nations to move away from fossil fuels in order to achieve Net Zero by 2050¹¹. However, there was no target date assigned for the complete phase out of fossil fuels¹². Other steps were included to achieve climate goals, including an increase in energy efficiency and renewable energy. There was a full day designated to discussions related to urbanisation, built environment and transport. A key moment relating to the built environment was the launch of The Cement and Concrete Breakthrough by UAE and Canada, with a goal to establishing near-zero emission cement projection and making it the preferred choice in global markets. Focusing on transport, there was a strong emphasis on ways to achieve national targets, including active travel, public and shared transport, and the use of electric vehicles. These advances are supported through initiatives like LOTUS.

There has been significant progress across Europe in establishing policies and pledges to decarbonize road transport, although their networks are in the early stages of development or are yet to start. It is also recognized that although there is huge potential to reduce carbon emission across the construction, maintenance and operation of the TI sector, there are limitations on the power of transport administrations to instigate and initiate the changes required. Initiatives to incentivize the use of public transport, installation of EV charging points and decarbonization of the grid are often beyond the remit of transport administrations. The choice to use green electricity, LED lighting and the modification of procurement procedures to facilitate lower carbon materials for use on their networks are examples of strategies that are within their control.

While many countries have set strategies and targets for achieving net-zero, not many countries have specific policies or targets relating to circularity. In March 2020, the European Commission published a new Circular Economy Action Plan (CEAP) with the goal of

⁶ [COP26 energizes the shift to clean electric transport - Climate Champions \(unfccc.int\)](https://unfccc.int/news/cop26-energizes-the-shift-to-clean-electric-transport)

⁷ [What do the outcomes of COP26 mean for infrastructure? \(github.org\)](https://github.com/infrastructure/)

⁸ [Public transport part of the solution at COP27: Mohamed Mezghani | UITP](#)

⁹ [COP27: where was public transportation? | Automotive World](#)

¹⁰ [Key role for public transport in climate conference initiatives | UITP](#)

¹¹ <https://www.cop28.com/en/>

¹² <https://www.irishtimes.com/environment/climate-crisis/2023/12/13/cop28-climate-summit-approves-deal-to-transition-away-from-fossil-fuels/>



reducing waste and making products more sustainable as part of its European Green Deal Strategy^{13,14}. In response, a number of European nations are placing greater emphasis on circularity and developing policies and strategies to pursue European guidelines.

The European Circular Economy Stakeholder Platform (ECESP)¹⁵ was established in 2017 and is a European stakeholder led platform to encourage and facilitate the exchange of good practices across countries and sectors. There is a website which allows users to search existing good practices identified, add recommendations, access published reports and browse various adopted strategies. An annual conference is held to increase participation and disseminate advances in the area. It is supported by the European Commission and The European Economic and Social Committee.

Netherlands: The Netherlands have been drivers in circularity for many years, developing the first national Circularity Gap Report in 2018, to facilitate the measurement and monitoring of the progress towards circularity¹⁶. This led to the establishment of the Circularity Gap Reporting Initiative (CGRi) and the publication of annual global circularity metrics¹⁷. The goal is for a completely circular Dutch economy by 2050¹⁸, by using:

- Resource efficiency and maximum utility of raw materials in existing supply chains to decrease the demand for raw materials
- Products and raw materials that are renewable, non-critical and sustainably produced
- Innovation relating to production methods, product design and consumption¹⁹

Ireland: In Ireland, the Circular Economy Law was signed into law in July 2022, with the goal to minimize waste and increase resource efficiency. This includes the introduction of a regulatory system to ensure the sustainable and safe re-use of thousands of tons of waste material, which is particularly relevant to the transport sector²⁰.

UK: In 2017, the UK became the first country in Europe to publish a circular economy standard (BS8001:2017 Framework for implementing the principles of the circular economy in organizations), outlining best CE practices and guidelines within organizations.

Spain: In June 2020, the Spanish Circular Economy Strategy (Circular Spain 2030) was adopted in Spain. It lays the foundations to promote a new production and consumption model in which the value of products, materials and resources are maintained in the economy for as long as possible, and the generation of waste is minimized. The Strategy thus contributes to Spain's efforts to achieve a

¹³ [EUR-Lex - 52020DC0098 - EN - EUR-Lex \(europa.eu\)](#)

¹⁴ [Circular economy action plan \(europa.eu\)](#)

¹⁵ [About the Platform | European Circular Economy Stakeholder Platform \(europa.eu\)](#)

¹⁶ [Pioneers of the future: the countries leading the way with circular economy policy \(circle-economy.com\)](#)

¹⁷ [National Circularity Gap Metric - Circularity Gap Reporting Initiative \(circularity-gap.world\)](#)

¹⁸ [Circular Dutch economy by 2050 | Circular economy | Government.nl](#)

¹⁹ [A Circular Economy in the Netherlands by 2050. | UNEP Law and Environment Assistance Platform](#)

²⁰ [gov.ie - Landmark Circular Economy Act signed into law \(www.gov.ie\)](#)



sustainable, decarbonized, resource-efficient and competitive economy. It is to be implemented by means of successive action plans that are structured around five axes:

- production
- consumption
- waste management
- secondary raw materials and water reuse
- purification

Currently the Circular Economy Action Plan 2021-2023 is in progress²¹. Regarding waste management, in April 2022, Spain passed the Law 7/2022 containing regulations relating to waste and contaminated soil and the promotion of the circular economy. The Law aims to establish the principles of the circular economy through basic waste legislation, as well as contribute to the fight against climate change.

Portugal: In Portugal, the Legal Regime for Waste Management (RJGR) DL nº 488/1985²² was created in 1985. The main objective was to encourage less waste production, the development of technological processes that enable waste to be recycled, the disposal of non-recycled waste under conditions of maximum use of its energy and adequate protection of the environment. In 2006, a new law was passed regarding waste management, with the development of the General Waste Management Regime (RGGR) DL nº178/2006²³. The Regime was applied to waste management operations aimed at preventing or reducing the generation of waste, its harmful character and the adverse impacts arising from its generation and management, as well as reducing the impacts associated with the use of resources, to improve the efficiency of their use and the protection of the environment and human health. In 2008, a law was created specifically related to construction and demolition waste (CDW) management. At that time, the construction sector was responsible for a significant portion of the waste produced in Portugal, and in some cases, this waste was very heterogeneous with variable levels of danger. Up to this point, the management of CDW was regulated by the general waste management regime, as well as by specific legislation relating to the special flows often contained in CDW, such as packaging waste, waste electrical and electronic equipment, polychlorinated polyphenyls (PCBs), used oils and used tires. However, there were often difficulties and issues associated with this waste stream, resulting in environmentally undesirable situations, such as the uncontrolled disposal of CDW, which was not in accordance with the national objectives in terms of environmental performance. This provided a clear need to create legal conditions for the management of CDW, prioritizing the prevention of production and hazards, the use of sorting at source, recycling and other forms of recovery. The

²¹ https://www.miteco.gob.es/content/dam/miteco/es/calidad-y-evaluacion-ambiental/temas/economia-circular/200714eeec_resumenejecutivo_en_tcm30-510578.pdf

²² Decree Law No. 488/85 of 25 November of the Presidency of the Council of Ministers. Diário da República: I série, No 271 (1985). Accessed 20 October 2023

²³ Decree Law No. 178/06 of 5 September of the Ministry of the Environment, Spatial Planning and Regional Development. Diário da República: I série, No 171 (2006). Accessed 20 October 2023



basis of this new law was to create an approach that could guarantee the environmental sustainability of construction activities in a life cycle logic, where defined methodologies and practices are adopted during the design and execution phase, adhering to the waste management hierarchy.

In 2017, the Action Plan for the Circular Economy in Portugal was announced. The Action Plan for the Circular Economy was the result of the work of representatives from the Ministries of Science, Technology and Higher Education, the Ministry of the Economy, the Ministry of the Environment, and the Ministry of Agriculture, Forestry and Rural Development. Aligned with the European Union's (EU) Circular Economy Action Plan, the Paris Agreement, the EU's Industrial Policy Strategy and the United Nations' 2030 Agenda for Sustainable Development Goals, actions at three levels were identified:

- Cross-cutting actions - consolidated actions from various government areas for this transition and included actions such as developing partnerships for innovation and promoting the financing of solutions that accelerate the transition to the circular economy.
- Sectoral agendas - especially for more resource-intensive and export-oriented sectors. At this level, the lines launched by the ECAP were guidelines that can be appropriated by the sectors and complemented with other initiatives.
- Regional agendas - adapted to the socio-economic specificities of each region, and which included the identification of industrial symbiosis networks and the sharing of good practices for the circular economy in an urban context.

Accelerating the transition to the circular economy was not limited to this plan: other policy instruments contributed to the same end in specific areas such as carbon neutrality, spatial planning, the blue economy, the bioeconomy, organic farming, youth entrepreneurship, SIMPLEX, green public procurement and urban regeneration.

In 2016, following the COP 2016, Portugal established a goal to reduce its GHG emissions from -18% to -23% by 2020 and from -30% to -40% by 2030. In the Roadmap, it was stated that it was possible to achieve national emissions reductions of between -50% and -60%, compared to 1990, which corresponds to a reduction of -60% to -70% in the energy sector compared to 1990.

In 2020, the general waste management regime was approved, and the legal regime for the landfill of waste amended the regime for the management of specific waste streams, transposing Directives (EU) 2018/849, 2018/850, 2018/851 and 2018/852.

Finally, in 2021 the Basic Climate Law (Law no. 98/2021²⁴), was approved by Parliament, consolidating objectives, principles, and obligations for the different

²⁴ Decree Law No. 98/21 of 31 December of the Parliament. Diário da República: I série, No 253 (2021). Accessed 20 October 2023



levels of governance for climate action through public policies and establishing new provisions in terms of climate policy, namely:

- Stipulating rights and duties in climate matters, reinforcing the right to citizen participation.
- Defining the governance framework for climate policy, creating new structures and requirements, including the Council for Climate Action, municipal and regional climate action plans, and carbon budgets - which, in line with the other existing instruments, establishes the need for national targets for shorter sub-periods, in this case every 5 years.
- Creating new requirements and establishing timetables for climate policy planning and evaluation instruments, including the development of five-year sectoral plans for mitigation and adaptation, and a green industrial strategy aimed at supporting the industrial sector in the climate transition process.
- Defining new principles and standards for economic and financial instruments, with a particular focus on the government's budgetary process, green taxation and sustainable financing, promoting a just transition to a carbon-neutral economy.

The Basic Climate Law (LBC) thus established a set of obligations regarding the need to develop new climate policy instruments, including Regional Climate Action Plans (PRAC) and Municipal Climate Action Plans (Art. 14 - Regional and local climate policies).

While in general, there is more of an emphasis on net-zero than circularity, it is recognized that the two areas are not independent, adoption of resource efficiency and circular principles are essential to achieve net-zero. A number of national road and rail administrations have specific circular strategies in place which will facilitate the achievement of organizational and national net-zero targets. Specific implementation strategies adopted by transport administrators will be discussed further in Part B.

2.1.3. Barriers

Although in terms of European and national policies and strategies, there has been significant progress over the last number of years towards the goal of achieving a circular economy, many obstacles and barriers exist that ultimately hinder progress. Examples include:

- Lack of public understanding
- Political constraints on a national and international level
- Lack of investment in infrastructure to the required level²⁵

²⁵ [Which countries are leading the change in circular economy? - Construcia \(construcia.com\)](https://www.construcia.com/en/which-countries-are-leading-the-change-in-circular-economy/)



To achieve a circular economy, change is required across Europe and beyond, since the supply of raw materials and waste flows are global. Small and Medium-sized Enterprises (SMEs) and organizations within the supply chain may resist this sustainable transformation towards circularity and may not recognize that, as well as environmental benefits, there are potential positive societal and economic benefits of this transition²⁵. Procurement policies by national administrations have a great influence on the supply chain. In parallel with this, standards must be amended to encourage innovation of lower carbon solutions and foster the development and implementation of new technologies, materials and methods to achieve decarbonization.

A review of circularity within national road authorities (NRAs) found that many NRAs were including CE principles without formally implementing CE policies or strategies²⁶. Many were implemented as part of previous sustainability initiatives (e.g., recycling, resource efficiency and use of waste materials). The barriers hindering implementation of formal CE practices were highlighted as inadequate testing and confidence regarding technical performance of recycled materials, technological and administrative limitations which ultimately leads to a difficulty in avoiding downgrading of recycled materials. Further challenges include budget restrictions and lack of clear standards and regulations to support circular principles and incentivize change²⁶.

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.

The current lack of data and transparency in the success of implemented strategies and technologies creates a potential barrier between management agencies' ambition and the supply chain. Although there has been significant progress in various carbon emission reduction strategies, there is limited publication of the quantification of associated benefits. 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.

There are many challenges and obstacles to implementing more comprehensive and ambitious laws and policies in the transportation sector that promote sustainability, circular principles, and environmental conservation. Some of the main difficulties and obstacles include²⁷:

- **Investment Constraints:** One of the primary challenges in implementing sustainable transportation measures is the availability of funding and resources. Developing and maintaining sustainable transportation infrastructure, such as improved public transit systems or EV charging networks, requires significant investment. Budget constraints may limit the speed and scope of such projects.

²⁶ Mantalovas, K.; Di Mino, G.; Jimenez Del Barco Carrion, A.; Keijzer, E.; Kalman, B.; Parry, T.; Lo Presti, D. European National Road Authorities and Circular Economy: An Insight into Their Approaches. Sustainability 2020, 12, 7160. <https://doi.org/10.3390/su12177160>

²⁷ Mota, P. M. F. (2016). Avaliação do desempenho das políticas de Ambiente em Portugal (Doctoral dissertation).



- Infrastructure Development: Upgrading or developing new transportation infrastructure to align with sustainability goals can be slow and complex. Land use issues, permitting processes, and coordination between various authorities can create delays and obstacles.
- Intermodal Connectivity: Achieving efficient intermodal transportation connections can be challenging. Integrating different modes of transportation, such as railways, buses, trams, and cycling options, requires careful planning and coordination between multiple agencies and stakeholders.
- Changing Public Behaviour: Shifting public behaviour and preferences towards more sustainable transportation options can be challenging. Many people are accustomed to using personal vehicles and may be resistant to change. Effective public awareness campaigns and incentives are needed to encourage the adoption of sustainable transportation.
- Political and Regulatory Hurdles: Political considerations and regulatory obstacles can slow down the implementation of sustainable transportation measures. Political will and policy stability are critical to ensure the continuity of sustainable initiatives across different administrations.
- Technological and Innovation Gaps: Keeping pace with rapidly evolving transportation technologies, such as electric and autonomous vehicles, can be a challenge. Policymakers and regulators must continually adapt to these changes to create a supportive regulatory environment.
- Lack of Incentives: The absence of sufficient incentives for sustainable transportation choices, such as subsidies for public transportation, EV purchase incentives, or congestion pricing, can discourage individuals from choosing eco-friendly options.
- Data and Metrics: Effective policy implementation requires accurate data and performance metrics. Data collection, monitoring, and evaluation can be challenging, especially in the context of sustainability initiatives.
- Cultural and Behavioural Factors: Social and cultural factors play a role in transportation choices. Encouraging walking, cycling, and public transportation may require addressing cultural norms and habits that favour car ownership.
- Geographical and Demographic Variation: Geography and population distribution can pose challenges, in Portugal for example. In rural areas, access to sustainable transportation options may be limited, and addressing this disparity is complex.
- Economic Impacts: Implementing sustainable transportation policies may have economic implications, including job displacement in traditional industries, which can be a political challenge.
- Environmental and Land Use Constraints: Protecting natural and cultural resources while expanding transportation infrastructure can be difficult. Balancing environmental conservation with infrastructure development is a complex issue.



2.2. Definition of circularity in the context of transport infrastructure

2.2.1. Introduction

Since the concept of circularity emerged, many definitions of circular economy have been presented, primarily focused on improving resource use and efficiency. The Ellen McArthur Foundation describes the circular economy as:

“A circular economy is one that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at all times²⁸.”

The goal is to develop a positive continuous cycle that preserves and enhances natural capital, optimizes available resources and minimizes supply chain risk by managing finite stocks and flow of materials. This aims to decouple economic growth and the use of finite virgin materials.

Within TI, as part of their commitment to sustainability, over the last decade the road sector has focused on increasing rates of recycling in asphalt roads and using lower temperature asphalt in road construction to reduce energy consumption. Although this forms part of the ethos of circularity, there is more scope to encompass the principles of circular economy and resource efficiency within TI.

The concept of the ‘9Rs’ was introduced to illustrate the varying degrees of effectiveness of different strategies in the move towards circularity. Many people are familiar with the ‘3Rs’ commonly known as ‘Reduce, Reuse, Recycle’, which were used to promote sustainable maintenance. The aim is to use these steps in order, with reduce being the most advantageous and having the highest impact on sustainability and recycle having the lesser impact of the ‘3Rs’. The idea was to encourage people to use less energy and produce less waste and emissions. With circularity becoming an emerging priority, this concept has been extended to ‘9Rs’ to provide a more comprehensive outline of the various options with an indication of the relative impact of each stage. The ‘9Rs’ concept illustrating the various stages in the move from a linear to a circular economy is shown in Figure 4. The 9 stages are Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle. A 10th R is often included as part of the 9Rs definition, Recover, which can involve incineration to recover embodied energy from waste or residues²⁹.

Circularity involves more than just recycling and entails a fundamental re-evaluation of how valuable resources can be used and maintained at their highest utility. A key element is through efficient design and designing out waste and pollution rather than addressing these downstream after they are produced. The overarching objective is to generate a closed loop system that looks at the life cycle of a product or service, not necessarily to minimize the

²⁸ Ellen MacArthur Foundation, Towards a circular economy: Business rationale for an accelerated transition (2015)

²⁹ [categorisation system for the ce.pdf \(europa.eu\)](#)



cradle-to-grave resource consumption, but to generate cyclical, cradle-to-cradle flow of materials to enable materials to maintain their status as high value resources.

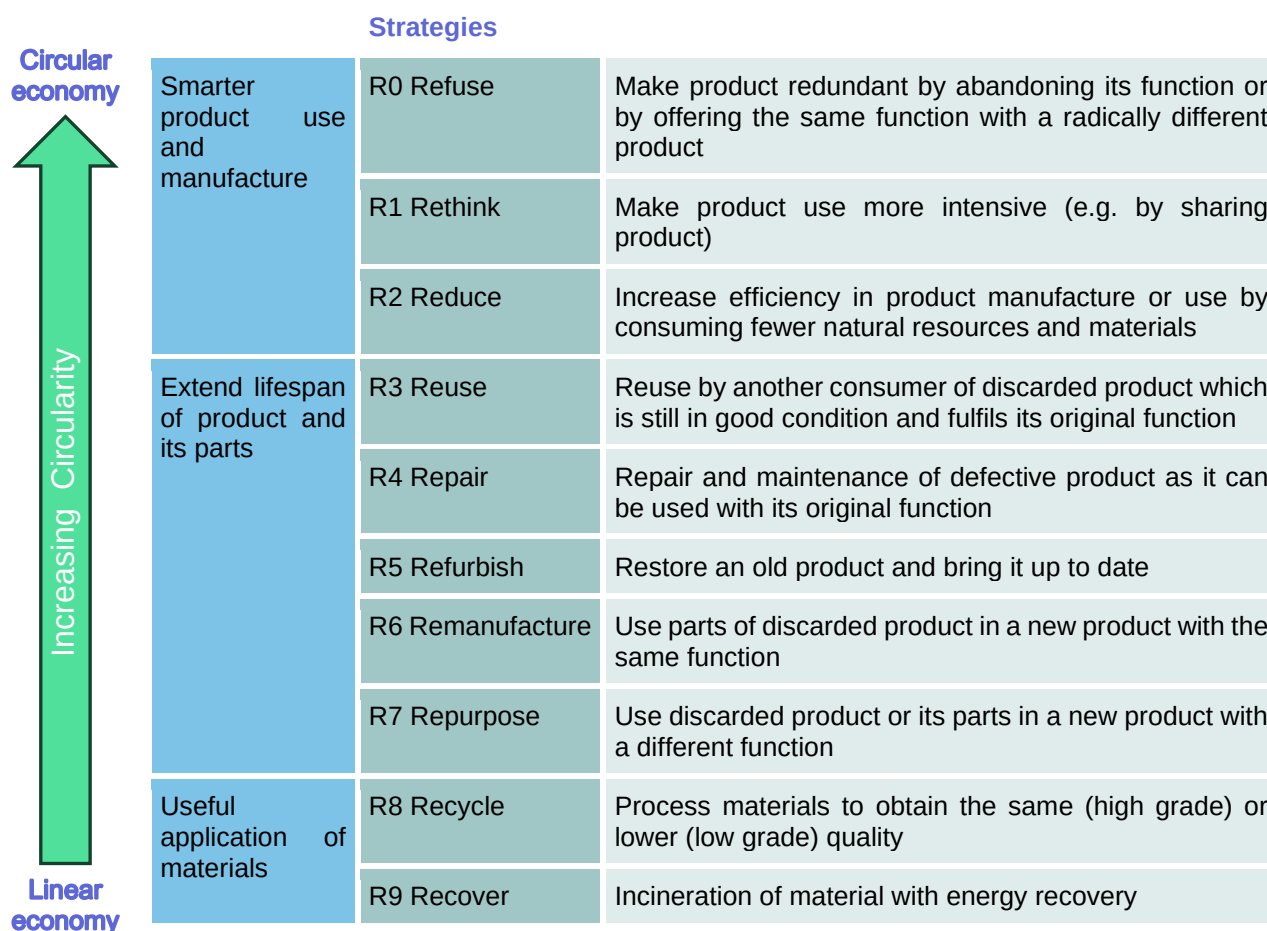


Figure 4 9 'Rs of the Circular Economy (reproduced from Kirchherr et al.³⁰)

Regarding TI, and its importance for economic growth and considering the condition of existing infrastructure, R0 Refuse and R1 Rethink are generally not considered feasible. Many existing structures were not designed with future recyclability or disassembly in mind. TI construction, operation and maintenance can span several of the stages in Figure 4, depending on the scope and type of project. This concept can be used to assess current levels within a project or organization and provide guidance and motivation on how to progress towards a more circular model. Currently, the most common practices within construction and maintenance activities are recycling of materials (R8) and the inclusion of secondary materials (R7).

Other examples of how circularity has been interpreted in construction are given in Table 2.

³⁰ Kirchherr, J, Reike, D & Hekkert, M.P.. (2017). Conceptualizing the Circular Economy: An Analysis of 114 Definitions. SSRN Electronic Journal. 127. 10.2139/ssrn.3037579.



Table 2 Examples of the interpretation of circularity

Source	Interpretation
Ellen MacArthur Foundation (2015)²⁸	• Preserve and enhance natural capital • Optimize resource yields by circulating products at the highest utility • Foster system effectiveness with sustainable design
CRGi (2022)³¹	• Virgin materials are not extracted for construction materials • Maximize the cycling of construction and demolition waste in new buildings
CIRCulT (2021)³² – Circular Economy Wiki supported by a Horizon 2020 project	• Does not deplete natural non-renewable resources • When in use, materials have no adverse impact on the environment
Platform CB'23 (2022)³³ – Measuring circularity guide – A measurement method for circular construction	• Protection of virgin material stocks and minimizing waste material • Protection of the environment through all life cycle phases • Protection of residual value of existing materials
Mi-ROG (2018)³⁴ – White paper by the UK Major Infrastructure Resource Optimisation Group	• Maintain resources in use for as long as possible • Extract the maximum use from resources while in use • Recover and renew products and materials at the end of life • Keep products, components and resources at their highest utility and value at all times
CERCOM Deliverable D2.1 (2022)³⁵ – Good practice inventory of current systems and procurement methods	• Minimizing consumption of natural resources • Designing out waste and keeping resources in use and at their highest level of utility • Optimizing the value obtained within each lifecycle • Improving environmental performance and contributing to societal development

³¹ CGRi (2022) Circularity Gap Reporting Initiative <https://www.circularity-gap.world/norway> accessed on 28/07/2023.

³² CIRCulT (2021) Sustainable materials for construction. Article downloads from [Sustainable materials for construction - Designing Buildings](#) on 28/07/2023.

³³ Platform CB'23 (2022). Measuring circularity guide – A measurement method for circular construction. Delft: Platform CB'23. Downloaded from <https://platformcb23.nl/downloads> (Microsoft Word - Measuring Circularity Guide.docx (platformcb23.nl)).

³⁴ MI-ROG (2018) Measuring circular economy performance – suggestions for infrastructure organisations. White paper No.2. Downloaded from [180037UKI MI-ROG White-paper 0.6.pdf \(aecom.com\)](#) on 28/07/2023.

³⁵ CERCOM Deliverable D2.1 (2022), Good practice inventory of current systems and procurement methods ([Overview of Research Programmes Operations \(cedr.eu\)](#))



A project entitled CERCOM³⁶ (Circular Economy in Road Construction and Maintenance) ran from September 2021 to August 2023 and was funded by the Conference of European Directors of Roads (CEDR)³⁷. CERCOM investigated how circular economy initiatives could be incorporated in the context of highway construction and maintenance and what barriers and opportunities existed for its adoption. One of the aims 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 national roads authorities. This work provides useful background to the LIAISON Circularity definition.

2.2.2. Definition of circularity for LIAISON project

The LIAISON project promotes circular infrastructure, energy efficiency and the adoption of renewable energy sources with the goal of making TI climate-neutral, sustainable and circular. The project will develop and implement sustainable solutions throughout the life cycle of European roads and railways. The project will offer a comprehensive methodology, supportive tools, and near-market technological solutions aimed at transforming the EU TI into a more sustainable economic activity. The development of the LIAISON Dynamic Multi-Infrastructure Governance Framework (DMIGF) will facilitate activation, articulation and monitoring of innovations' compliance with circular economy principles throughout the life of the TI. However, to achieve these goals, it is essential to first outline the definition of circularity in the context of the LIAISON project.

In practice, attempts to address a scope that is too broad are unlikely to be successful since the data to support measurement of performance or assessment of the circularity of different maintenance options is unlikely to be available. Furthermore, various TI administrations will differ in the approaches and extent to which they have already implemented circularity principles. Given the knowledge acquired through CERCOM, the definition of CE proposed by CERCOM is taken as the initial starting point for LIAISON, with the intention that the definition will be amended and developed as the project progresses. On this basis, the adopted definition of CE is outlined below.

Circular Economy and Resource Efficiency for Transport Infrastructure means, by design:

- *Minimizing consumption of natural resources.*
- *Designing out waste and keeping resources in use and at their highest level of utility.*
- *Optimizing the value obtained within each lifecycle.*
- *Improving environmental performance and contributing to societal development.*

³⁶ [Circular Economy in Road Construction and Maintenance - CERCOM \(cedr.eu\)](https://cedr.eu/circular-economy-in-road-construction-and-maintenance-cercom)

³⁷ CEDR (2020), <https://www.cedr.eu/peb-call-2020-resource-efficiency-and-circular-economy>



3. Current HE projects: Circuit³⁸

The public document D1.1 – Report on the CIRCUIT Holistic Framework with Quantifiable KPIs for Circular, Smart, Resilient, and Sustainable Transport Infrastructure involved an extensive literature review to develop the CIRCUIT holistic framework. The review encompassed an overview of European strategic and legal frameworks, previous research, and EU projects such as LCE4Roads, ASHVIN, and FORESEE, as well as existing sustainable frameworks and rating methodologies like ENVISION and BREEAM Infrastructure. It also examined relevant CEN standards related to construction sustainability, including EN 17472, ISO 21929-1, CWA 17089, and environmental product declarations (EN 15804), along with frameworks addressing resilience (CWA 17819) and life cycle costing (ISO 15686).

Building on this foundation and through a collaborative process involving various organizations within the CIRCUIT consortium—representing the entire supply-value chain of transport infrastructure (including designers, material producers, contractors, asset owners, and researchers)—a comprehensive circularity framework has been proposed. This framework integrates methodologies for assessing resilience, economic viability, circularity, and environmental impact. It introduces quantifiable KPI metrics that encompass four dimensions: social aspects (including resilience), economy, environment, and circularity, with digitalization as an additional factor. The assessment of social performance is distinct from that of economic and environmental factors, as it requires both quantitative and qualitative approaches. The CIRCUIT framework encompasses the entire life cycle, from performance-based design and construction to maintenance, operation, decommissioning, and end-of-life considerations for transport infrastructure, but not the procurement process.

³⁸ [Document Template \(circuitproject.eu\)](https://circuitproject.eu)



4. International lookout and trends in circular uptake

4.1. Implementation strategies adopted by Transport Administrations

Road and rail administrations' policies in Europe are generally linked to national net-zero targets and commitments. The goal is to focus on reducing emissions while maintaining and delivering TI that is fundamental to the economic well-being of society.

Internationally, there are three classifications which are generally used to describe and categorize different sources of emissions³⁹. In the context of TI administrations, they can be summarized as:

Scope 1 – This covers emissions from sources directly within the control of the TI administrations and are the direct result of their activities (e.g., the fuel used in their fleet vehicles (non-EVs)).

Scope 2 – This relates to indirect emissions associated with the activities of the TI administration based on emissions from purchased energy (e.g., the electricity purchased by the TI administrations and used to power offices/EVs). The emissions physically occur at the location where the energy is produced.

Scope 3 – This covers indirect emissions associated with the TI administrations that are not within Scope 2. These are indirect emissions associated with activities up and down the TI administration's supply chain (i.e., the emissions are linked to TI administrations operations but not controlled directly). For example, the use of goods purchased from a supplier or from the company's own products when customers use them. These emissions are more difficult to quantify but also more difficult for TI administrations to control.

For transformational change to occur, it is essential that CE principles are embedded in the business strategy, values and organizational culture. Outlining a clear policy and organizational objectives with strong visible leadership will instigate transition to circularity.

Some initiatives employed by TI administrations to reduce carbon emissions include:

- Transition to electric vehicles (EVs)
- Encouraging non-motorized transport
- Encouraging public transport
- Low carbon construction or maintenance
- Energy generation systems

³⁹ Greenhouse Gas Protocol ([FAQ.pdf \(ghgprotocol.org\)](https://ghgprotocol.org/))



- Decarbonization of corporate emissions

The national road authority in Ireland, Transport Infrastructure Ireland (TII), have developed and adopted a bespoke Circular Economy Plan based on the principles of the ‘9Rs’ of circularity⁴⁰. The goal is to adopt a circular economy approach across all activities and projects through optimization of asset use, life cycle assessment, re-engineering of business systems, collaboration with supply chain, effective procurement, information and material management. On a project basis, the primary objectives are to:

- Design out waste through efficient resource use to protect existing material stocks.
- Keep assets, components and materials at their highest utility at all times.
- Encourage regenerative or restorative design.

Ireland’s national railway administration, Iarnród Éireann have addressed circular targets and goals within the Sustainability Strategy 2021 – 2030⁴¹. They have committed to:

“Transform our business to minimise impacts on and maximise benefits to the environment, protecting our environment and enhancing biodiversity; and prioritising circular economy initiatives and waste management”⁴¹.

This includes a range of targets to be met by 2030, including:

- Recycling 70% of all waste, general and construction.
- 25% of raw material purchases to come from recycled sources.
- All contracts for sleeper disposal to prioritize reuse of material.
- Create a more sustainable procurement process where major contract specifications request green alternatives, while tender evaluations incorporate weighting favouring these alternatives.

SNCF RESEAU in France has established a dedicated task force comprising of 10 people, responsible for developing a CE strategy with the goal of reusing or recycling 100% of main rail components by 2025 (rail, ballast, wooden and concrete sleepers and copper wires). The process involved in achieving this ambitious target is the implementation of carefully planned small-scale projects that can be scaled up over time⁴².

Swiss Federal Railways (SBB) is one of the largest providers of external contracts within the Swiss railway sector. This results in large material flows throughout Europe and provides the company with a significant platform to instigate change in the move towards circularity across the railway sector. In 2021, SBB established a Centre of Excellence to initiate and develop circular principles and business models that will be put into action over the coming

⁴⁰ Lynch J. TII circular economy plan: TII standards training
https://www.tiipublications.ie/training/SRT22/day1/05_j_lynch_TII_circular_economy_plan.pdf

⁴¹ Iarnród Éireann Sustainability Strategy 2021 – 2030 [SustainabilityE \(irishrail.ie\)](https://www.irishrail.ie/Sustainability)

⁴² [Circular practices in the railway and ways forward - REUSE Project final Report \(uic.org\)](https://www.reuse-project.eu/reports/circular-practices-in-the-railway-and-ways-forward)



years⁴³. The following three areas were identified as priorities for the introduction of circular business practices:

- Reducing the input of raw materials
- Extending and intensifying use
- Actively preserving materials

In 2016, Highways England (now called National Highways), the national road authority in England, published a publicly available roadmap towards circular economy in collaboration with AECOM and Atkins⁴⁴. This covers the areas of governance, procurement, monitoring, reporting and development of tools and guidelines. The goal was to use ‘pathfinder projects’ to develop and record practical application of the CE roadmap at a project level for the purpose of knowledge building and lessons learned.

In January 2019, Network Rail in the United Kingdom launched an internal circular economy app called ‘SURPLUS’ aimed at facilitating the internal redistribution of assets within the company⁴². As well as encouraging greater sustainability, it also results in cost efficiencies. It encourages users to sell unwanted resources to other Network Rail sites allowing them to be reused rather than sent to landfill. Network Rail has a rail recycling centre, where typically between 40 and 50 wagons arrive each week⁴². Examples of materials that arrive at the facility include track panels, sleepers, rails, small steel components, crossing units and switch components. They are separated and graded into materials that can be reused on the network and others to be sold onto external bodies. Ballast is cleaned to remove all hazardous contaminants before being re-used or sold.

In Spain, within the Circular Economy Action Plan 2021-2023, the Railway Infrastructure Administrator (ADIF) has established several lines of action, such as the preparation of a catalogue of environmental and social criteria for contracting railway infrastructure, with the aim of promoting the principles of the circular economy and green contracting, a comprehensive program for the recovery of disused railway assets, and the effective management of surplus land from railway infrastructure works to promote the environmental recovery of degraded environments or the use in other works⁴⁵.

Within the same plan, the General Directorate of Highways of the Spanish Ministry of Transport, Mobility and Urban Agenda (MITMA), is preparing recommendations to promote the use of Secondary Raw Materials (SRM) on roads, such as the use of steel slag from steel mills in bituminous mixture wearing layers, or waste from out-of-use tires on road embankments. Another line of activity is the preparation of instructions for increasing the reuse of existing material in pavement rehabilitation works⁴⁶.

Portugal has been making efforts to promote sustainable transportation, which aligns with circular economy principles. This includes investments in public transportation, cycling infrastructure, and electric vehicle charging networks. These initiatives aim to reduce the

⁴³ [Circular economy | SBB](#)

⁴⁴ European National Road Authorities and Circular Economy: An Insight into Their Approaches, Sustainability, vol. 12(17), September 2020, <https://doi.org/10.3390/su12177160>.

⁴⁵ https://www.adif.es/w/economia-circular?p_l_back_url=%2Fsearch%3Fq%3Deconomia%2Bcircular

⁴⁶ https://www.miteco.gob.es/content/dam/miteco/es/calidad-y-evaluacion-ambiental/temas/economia-circular/plan_accion_eco_circular_def_nipo_tcm30-529618.pdf



environmental impact of transportation and promote the efficient use of resources. Some examples are:

- Public Transportation Improvements: Portugal has invested in improving its public transportation systems, including buses, trams, and trains. For example, the expansion of the Lisbon metro system and the introduction of more energy-efficient buses in major cities⁴⁷.
- Cycling Infrastructure: Portuguese cities like Lisbon and Porto have developed extensive cycling infrastructure, including bike lanes and bike-sharing programs, to encourage sustainable and circular transportation⁴⁸.

Circular principles in transportation also involve waste reduction and recycling efforts. Portugal has implemented policies to reduce waste generated from vehicles and promote recycling of vehicle parts and materials. This helps to extend the lifespan of vehicle components and reduce the environmental impact. These policies include^{49,50,51,52,53}:

- Waste Management Plans: Construction and demolition waste management plans are required for construction projects. These plans outline strategies for minimizing waste generation, recycling and reusing materials, and responsible disposal of construction-related waste.
- Recycling and Reuse of Construction Materials: There are efforts to encourage the recycling and reuse of construction materials. For example, concrete and masonry debris can be crushed and recycled as aggregates for new construction, reducing the need for virgin materials.
- Eco-Friendly Construction Practices: The construction industry is adopting eco-friendly building practices, including the use of sustainable building materials, energy-efficient designs, and waste reduction strategies. Green building certification systems, such as LEED or BREEAM, are also promoted.
- Circular Design and Building Techniques: Architects and builders are increasingly incorporating circular design principles into construction projects. This includes designing for disassembly, modular construction, and the use of materials that can be easily recycled or repurposed.
- Demolition and Deconstruction Techniques: Demolition practices are shifting towards deconstruction, where buildings are carefully disassembled to salvage valuable materials like wood, bricks, and metals. This reduces waste and promotes material reuse.

⁴⁷ Afonso, M. (2015). Transporte público e mobilidade mais sustentável (Public transport and more sustainable mobility). Instituto Superior Técnico de Lisboa, Lisboa. (In Portuguese)

⁴⁸ Ramos, P. A. M. (2008). Projecto de ciclovias. (Cycle path project) (In Portuguese)

⁴⁹ RCM No. 30/16 of 29 July of the Presidency of the Council of Ministers. Diário da República: I série, No 145 (2006). Accessed 20 October 2023

⁵⁰ Decree Law No. 31/23 of 24 March of the Presidency of the Council of Ministers. Diário da República: I série, No 60 (2023). Accessed 15 October 2023

⁵¹ Chula, P. M. C. (2014). Desenvolvimento sustentável em áreas urbanas de génese ilegal. (Sustainable development in urban areas of illegal origin) (In Portuguese)

⁵² de Sousa, A. F. (2020). Avaliação das metodologias de gestão da qualidade nos processos de gestão e de tratamento dos resíduos urbanos. (In Portuguese).

⁵³ Guimarães, J. (2023). O Desenvolvimento Sustentável por meio da Agenda 2030 ea implementação do ODS 5 em Portugal. Revue Française du Centre d'études Avancées en Éducation et Développement Durable, 1(1).



- Waste Separation and Recycling Facilities: Construction sites are equipped with waste separation facilities to sort and recycle materials like concrete, wood, metal, and plastic, ensuring that valuable resources are not sent to landfills.
- Extended Producer Responsibility (EPR): EPR programs require manufacturers and suppliers of construction materials to take responsibility for the environmental impact of their products, including their end-of-life disposal. This encourages product design that facilitates recycling and reuse.
- Public Procurement for Sustainable Construction: Government agencies may adopt green public procurement policies that require sustainable and circular practices in public construction projects, setting an example for the private sector.

In the field of railways, Portugal has implemented various measures and initiatives to promote circular principles and sustainability. These measures focus on reducing environmental impact, resource efficiency, and the responsible management of materials and waste. Here are some of the key measures and initiatives^{54,55,56,57}:

- Sustainable Railway Infrastructure Design: Portugal has been designing and upgrading railway infrastructure with a focus on sustainability. This includes the use of eco-friendly materials, energy-efficient technologies, and environmentally responsible construction practices.
- Recycling and Reuse of Railway Materials: The railway sector in Portugal, like the construction sector, promotes the recycling and reuse of materials whenever possible. This includes repurposing railway tracks, sleepers, and other components.
- Maintenance and Asset Management: A well-maintained railway system is more sustainable. Portugal invests in preventive maintenance and asset management to extend the lifespan of railway infrastructure and reduce the need for frequent replacements.
- Energy Efficiency and Electrification: Electrification of railway systems and the use of energy-efficient technologies in trains contribute to lower energy consumption and reduced environmental impact. Portugal has been investing in electrification projects.
- Waste Management and Recycling at Railway Facilities: Railway facilities and maintenance depots have waste management systems in place to separate and recycle materials, including metals and electronics from decommissioned railway equipment.
- Sustainable Procurement: When procuring railway equipment and services, Portugal's railway authorities may prioritize environmentally friendly and circular options. This includes considering factors such as the recyclability and energy efficiency of rolling stock and infrastructure components.
- Circular Design and Materials Innovation: Portugal, like many countries, is exploring circular design principles in railway engineering. This includes designing components

⁵⁴ Castro, G. J. D. F. (2017). Managing cultural differences in a merger process: infraestruturas de Portugal: merger between Refer and Estradas de Portugal (Doctoral dissertation).

⁵⁵ Ramos da Silva, T., Moura, B., & Monteiro, H. (2023). Life Cycle Assessment of Current Portuguese Railway and Future Decarbonization Scenarios. *Sustainability*, 15(14), 11355.

⁵⁶ Gonçalves, R. M., Martinho, A., & Oliveira, J. P. (2022). Recycling of reinforced glass fibers waste: Current status. *Materials*, 15(4), 1596.

⁵⁷ Meireles, M. J. D. (2020). Mobilidade Urbana Sustentável centrada no uso da bicicleta. Um sistema digital, integrado, partilhado e inteligente (Doctoral dissertation, Universidade do Minho (Portugal)).



and infrastructure to be easily disassembled, refurbished, and recycled at the end of their lifecycle.

- Research and Development: Research institutions and industry stakeholders in Portugal engage in projects focused on sustainable railway solutions. These projects aim to develop innovative technologies and materials to enhance the environmental performance of the railway sector.
- Multi-Modal Transportation Integration: Portugal is working on integrating railways with other modes of transportation, such as urban transit systems and intermodal facilities. This promotes a more efficient and sustainable transportation network, reducing the overall environmental impact of passenger and freight transport.
- Environmental Impact Assessments: Prior to railway construction and expansion projects, environmental impact assessments are conducted to identify and mitigate potential environmental effects. This helps ensure that projects adhere to sustainability and circular economy principles.

A review paper of circularity within national road authorities (NRAs) carried out by Mantalovaset al.⁵⁸ acknowledged that all NRAs contacted as part of the review had some knowledge of the principles of CE, particularly:

- Design out waste/minimize waste.
- Re-use waste.
- Extend lifespan of infrastructure.

The Netherlands and Austria's NRAs were the most advanced in terms of implementation of CE principles. In some countries, there was an understanding regarding various CE principles, but at the time of the survey none were currently implemented (e.g., Belgium, Norway, Lithuania). However, most NRAs were committed to preserving existing assets and reducing waste. In practice, this translates into various policies and procedures that inherently incorporate CE into ongoing construction and maintenance procedures, for example⁵⁸:

- Removing restrictions on asphalt recycling to reduce waste.
- Performing preventative maintenance to extend service life of pavements.
- Potential use of waste materials as a resource in asphalt pavements.

4.2. International practice and case studies

4.2.1. Examples from the Road Sector

Examples of international practice and case studies that have proven to successfully incorporate CE principles in TI construction projects are provided below.

⁵⁸ Mantalovas, K.; Di Mino, G.; Jimenez Del Barco Carrion, A.; Keijzer, E.; Kalman, B.; Parry, T.; Lo Presti, D. European National Road Authorities and Circular Economy: An Insight into Their Approaches. Sustainability 2020, 12, 7160. <https://doi.org/10.3390/su12177160>



4.2.1.1. Construction and Maintenance

Circular economy approaches have considerable potential to provide both carbon and economic savings in road construction and maintenance. Various examples of projects from the road sector that adopted circular principles, to varying degrees, were investigated and presented in the CERCOM Deliverable D4.3⁵⁹ and PIARC Special Report – Carbon Neutral Roads⁶⁰. A table summarizing the advances and findings as part of these projects is presented below.

Table 3 Advances of CE and case studies in the road sector

Project	Description	Outcomes and Lessons learned
A14 UK⁵⁹	- Cambridge to Huntingdon improvement scheme, National Highways first CE pathfinder project. - Collaboration with stakeholders throughout the supply chain. - CE approach only adopted at detailed design phase. - Particular attention to resource requirements and sourcing. - Workshops were held with technical leads to identify resource efficiency opportunities and identify those with potential for high impact and high feasibility.	- Regular communication to identify ‘best practice’ in the application of adopted CE strategies and document lessons learned. - Collaboration workshops identified many potential opportunities for CE and resource efficiency. Not all were adopted, but maintaining a list of potential proposals provides future similar projects with a head start on the road towards circularity. - The greatest potential for increasing circularity and reducing carbon in major infrastructure projects occurs during the feasibility and preliminary design phases of a project.
A303 UK^{59 60}	- Amesbury to Berwick road construction - first scheme in UK to adopt CE principles from preliminary design phase. - Aim to build awareness and promote CE within the industry. - Built on lessons learned from A14 CE Pathfinder project.	- Consideration of CE in early design phases showed greatest potential for advancement in circularity approaches. - Communication of potential CE and sustainability benefits of various approaches was beneficial. - From the potential measures identified, contractual mechanisms were used to implement chosen strategies. - A “live” document was maintained in collaboration with stakeholders to

⁵⁹ CERCOM Deliverable D4.3 (2023), Case study III – NRAs Strategic Approach to Transitioning to CE ([Overview of Research Programmes Operations \(cedr.eu\)](#))

⁶⁰ M. Lamb, H. Viner, V. Ramdas, L. Connolly and E. Sheils. Carbon Neutrality of the Road Sector. A PIARC Special Report, 2022.



Project	Description	Outcomes and Lessons learned
		identify further efficiencies and innovations. • Ongoing monitoring and metrics are beneficial to evaluate CE realization to inform benefits for future work.
A12 Netherlands 59 60	• Road reconstruction between Ede and Grisjoord junction in the Netherlands demonstrating use of low carbon construction and CE. • Tender procedure adopted Most Economically Advantageous Tender (MEAT) approach which enabled the selection of the bid that offered the best ratio of price to quality including assessment of CO₂ mitigation and reduction of environmental impacts.	• Extending standard product lifetime through smart and efficient design resulted in CO₂ emission reductions. • Setting CE and environmental targets early in the project when considering long term contracts for use, maintenance and end of life was beneficial. • Key development by Rijkswaterstaat was the consideration of ‘use and disposal’ at planning and procurement stage.
TII Case Study 59 60	• Improved efficiency in road design with the objective of “sweating the asset”. • TII are re-evaluating the process of road pavement design to allow for greater efficiency. • The new Irish Analytic Pavement Design Model (IAPDM) allows site specific conditions and material properties to be used in design, allowing for reduce, reuse or repurpose of materials to be considered. • This follows principles of circular economy by allowing for maximum utility of resources.	• This process allows for site specific conditions, where additional strength can be incorporated only where required, rather than as standard practice. This results in a reduction in resources required where sufficient strength can be verified. • A case study of a carriageway 11km long and 14m wide demonstrated a saving of over 11,000 tons of material. • This equates to a cost saving of approximately €834,000 and a carbon saving of 600,000 kgCO₂.



4.2.1.2. Reclaimed Asphalt Pavement (RAP)

A circular approach to the design of road infrastructure has the potential to have a significant impact on the goal of carbon reduction. In particular, for road construction, the use of Reclaimed Asphalt Pavement (RAP) is widely used given asphalt concrete is a fully recyclable material. According to PIARC Special Report – Carbon Neutral Roads⁶⁰:

“The proportion of RAP permitted in hot mix and warm mix asphalt mixes varies considerably in different countries. Studies have demonstrated the feasibility of producing bituminous mixtures with a high (over 40% wt.) or very high (up to 100% wt.) proportion of RAP, and negative perceptions can be addressed by good management practices to control the quality of the RAP, novel production technologies and advanced mix design.”

The challenge remains to reuse materials at the same level of utility rather than just downcycling for use in lower value applications (e.g., in unbound layers of pavement construction). Although additional materials have been investigated (slag, concrete, glass etc.), recycled aggregate is the most common choice of recyclable material to be incorporated into asphalt pavements. Using recycled aggregate rather than additional material additives means that the resource is retaining a high level of utility given it is reused for its original purpose⁴⁴.

In Ireland, TII conducted a case study involving a trial use of cold mix asphalt with up to 80% RAP on a 1.3km scheme on the R180 in County Monaghan. It involved the use of 3.5 tons of RAP in the base and binder courses, resulting in a 41% carbon saving when compared to a traditional hot mix asphalt design. This equates to carbon savings of approximately 44 tCO_{2e} per km⁶¹.

4.2.2. Examples from the rail sector

The rail sector also has ambition to increase circularity as well as reaching targets for decarbonization. High Speed 2 (HS2) is a major ongoing rail infrastructure project in the UK and was one of the first examples of a systems approach to circularity regarding planning and delivery of a large infrastructure project in the UK⁶². This included the publication of a report outlining the commitment to CE principles in 2017, where the underlying principles of CE for the project were identified to be:

- Keeping resources in use for as long as possible.
- Recovering and regenerating resources at the end of each use.
- Keeping resources at their highest quality and value at all times.

⁶¹ [TII Climate Action Roadmap](#)

⁶² CERCOM Deliverable D4.3 (2023), Case study III – NRAs Strategic Approach to Transitioning to CE ([Overview of Research Programmes Operations \(cedr.eu\)](#))



In Ireland, TII followed a circular approach for a light rail LUAS pilot project. A life cycle approach was followed for track design, taking into account Design for Deconstruction checklists. The excavation of material was carefully considered, with reuse of materials optimized using a hierarchical approach. To optimize resources and reduce waste, sharing of assets between TII and other agencies was explored⁶³.

There is an initiative implemented by Swiss Federal Railways (SBB) to encourage the reuse of tools, electrical installations, rails and other products or equipment that are no longer in service on the railway⁶⁴. The resources have not yet reached the end of their lifespan, and the goal is to maximize their residual value and avoid unnecessary waste. A dedicated online platform has been established to manage and sell these used materials from railway infrastructure.

4.2.3. Increase in the recycling of construction waste

A technical report published by the DecarboN8 project, indicates that on average, 70% of life cycle carbon emissions per km of road construction, lighting and maintenance are due to material production (primarily asphalt and concrete)⁶⁵, as illustrated in Figure 5. This demonstrates that adopting circular approaches to keep materials in use at the highest possible utility will have a significant impact on carbon emission reduction and the protection of virgin materials. Various individual measures were investigated to reduce the whole life carbon of new roads over a 40 year lifespan, for example, using low-carbon alternatives or secondary (reclaimed) materials. These measures individually had the potential to reduce the whole life carbon of new roads by between 2% and 12%. The largest impact was observed by replacing natural aggregates with 100% crushed concrete and construction rejects in the sub-grade and sub-base layer.

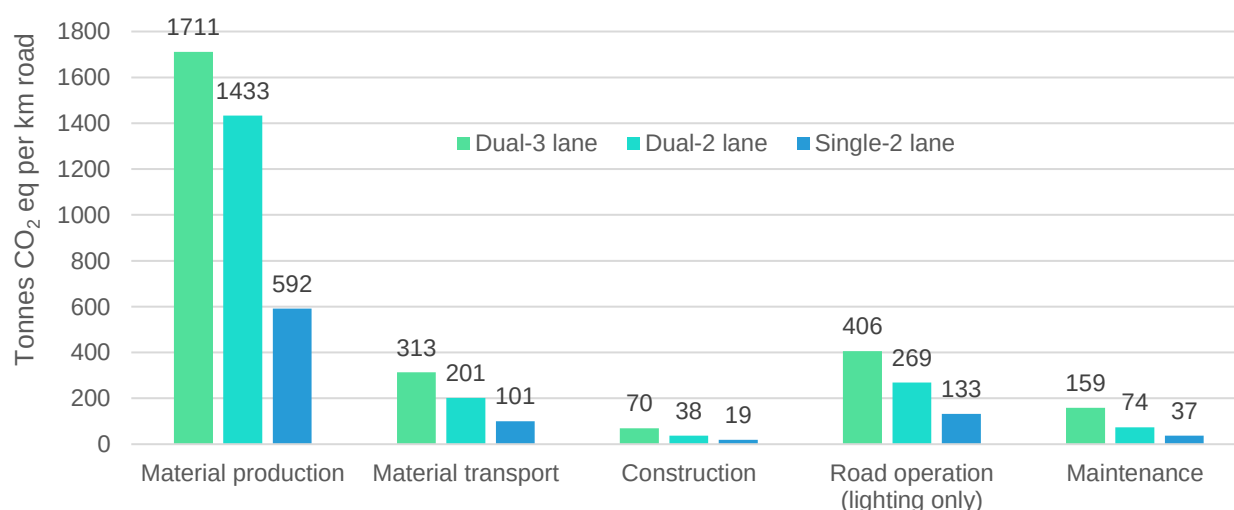


Figure 5 Life cycle carbon emissions associated with various forms of road pavement construction. Reproduced from DecarboN8 report⁶⁵

⁶³ [05_j_lynch_TII_circular_economy_plan.pdf \(tiipublications.ie\)](#)

⁶⁴ Swiss Federal Railways (SBB) Relate website, [SBB Resale](#)

⁶⁵ Lokesh, K., Densley-Tingley, D. and Marsden, G. (2022) Measuring Road Infrastructure Carbon: A 'critical' in transport's journey to net-zero. Leeds: DecarboN8 Research Network.



A Resource Exchange Mechanism (REM) being explored by National Highways in the UK is a move towards increased circularity and resource efficiency. The goal is to provide a tool to facilitate the exchange of surplus resources between schemes to reduce waste and the use of virgin materials. The study identified potential opportunities, requirements and barriers to implementation, but confirmed the feasibility in the use of REM to increase CE within the road infrastructure sector⁶².

An example of circularity and the use of construction waste from the rail sector is demonstrated with the Crossrail project in the UK. When complete, it will transport up to 200 million people each year to and from London and reduce the number of car trips by approximately 30,000 per day. This large tunnelling infrastructure project's sustainability goals include the reuse or recycle 95% of excavated earth. This led to a partnership with the charity The Royal Society for the Protection of Birds (RSPB) as part of the Wallasea Island Wild Coast Project. More than 4.5m tons of earth generated from the Crossrail project will be transported to Wallasea Island largely by road and rail to restore coastal marshlands and help protect land from rising sea levels⁶⁶.

4.2.4. Application of sustainable alternatives

It is estimated that 90% of the 5.2m km of the European road network is surfaced with asphalt mixtures, therefore, a significant number of resources, including materials, energy and manpower is required for the construction, maintenance and rehabilitation of pavements. Within the asphalt mixture components, the bitumen, although only used in approximately 5%, is the one with the greatest environmental and economic impact. Looking for sustainable, renewable, low-cost and environmentally friendly alternatives to petroleum asphalt that at the same time can withstand different loadings and environmental conditions on the road pavement remains a challenge. As a potential solution to this, bioasphalts have awakened interest due to their renewable origin, huge availability and expected environmental friendliness. A bioasphalt is an asphalt mixture in which a percentage of the fossil-based bitumen is replaced by a bio-binder.

Dynamic modulus, low-temperature performance, water sensitivity, rutting and fatigue resistance have been the most evaluated properties on bioasphalts from different sources. Pilot sections were implemented in 2021 in the Netherlands as part of the Chaplin XL project⁶⁷. The chemical company Avantium has produced a lignin-based bio-binder that is being used in a pilot section on the N987 replacing up to 50% of the petroleum-based bitumen⁶⁸. However, no information about the scaling up or the road performance is publicly available.

Despite the extensive research, the uptake of bioasphalt by road owners is still very limited, since there are several gaps and uncertainties that need to be addressed, such as:

⁶⁶ [Circular practices in the railway and ways forward - REUSE Project final Report \(uic.org\)](#)

⁶⁷ [CHAPLIN-XL - Copernicus Institute of Sustainable Development - Utrecht University \(uu.nl\)](#)

⁶⁸ <https://www.biofuelsdigest.com/bdigest/2021/06/06/lignin-leads-the-way-worlds-first-lignin-bio-asphalt-road-lignins-array-of-applications-and-more/>



- The long-term performance and durability.
- Understanding their aging resistance.
- The effect of bio-binders in different type of asphalt mixtures with different failure mechanisms.
- Optimal bio-binder content to ensure road requirements.
- Recyclability of bioasphalts.

There is also ongoing research into the potential use of alternative sustainable fuel sources for vehicles. For small vehicles and machinery, switching to battery power is an option to reduce carbon emissions. In some cases, due to remote location or charging time and weight of batteries for larger plant, alternative fuel sources may be more appropriate (e.g., biodiesel or hydrogen). Various options were assessed in the PIARC Special Report – Carbon Neutral Roads⁶⁹. In terms of convenience, biofuel has the advantage of being a direct replacement for diesel for existing machines. Although, there are sustainability issues, since the crops for biofuel are displacing agricultural land that is used for growing food. There are also concerns regarding the low efficiency of certain biofuel options. This area requires further development to provide sustainable long-term solutions.

The replacement of diesel power with hydrogen has two forms, production of hydrogen fuel cells to power vehicles and burning hydrogen in combustion engines. Currently the latter is the most popular option among plant manufacturers. Using hydrogen in this way means that engines can be produced similar to previous diesel combustion engines and existing engines can be retrofitted. However, fuel cells are more efficient than burning hydrogen, and some of the major plant manufacturers are in the process of producing and trialling prototypes. It is expected that the volume of machines powered by hydrogen fuel cells will increase over the next 5 to 10 years as they become more economically viable⁶⁹.

Network Rail in the UK installed composite railway sleepers made from recycled plastic across the weight-restricted Sherrington Viaduct, between Salisbury and Warminster⁶⁶. Traditionally, wooden sleepers would have been used over concrete on this line to reduce loading on the viaduct structure. These environmentally friendly alternatives to traditional wooden sleepers are designed for over 50 years of life and can then be re-used, re-purposed or recycled to make new sleepers or alternative products. They provide an increased service life and reduced maintenance and help Network Rail achieve a Zero Carbon target by 2050.

4.2.5. Smart systems and operation of TI

Across TI, many countries are switching to LED technology to replace inefficient lighting associated with high energy consumption and maintenance costs. LED lighting provides a high quality, efficient and low maintenance solution, with LED lamps lasting up to 20x longer than conventional lamps⁷⁰. The efficiency of LEDs can be further supplemented by smart controls. Considering energy savings, and the reduction in operation and maintenance

⁶⁹ M. Lamb, H. Viner, V. Ramdas, L. Connolly and E. Sheils. Carbon Neutrality of the Road Sector. A PIARC Special Report, 2022.

⁷⁰ United for Efficiency, [Lighting - United for Efficiency \(united4efficiency.org\)](https://www.united4efficiency.org/)



costs, payback on initial investment can in most cases be in the range of 4-8 years^{71,72}. By using smart technology, lighting levels and operations can be remotely controlled depending on the demand and site needs, using sensors, data analysis and control units. A deep dive investigation into the ongoing advances in LED lighting technology and the various options regarding implementation and operation was conducted as part of the PIARC Special Report – Carbon Neutral Roads⁶⁹. Conclusions indicate the potential carbon saving from switching to LEDs can vary widely depending on the source of power and whether the source of power is largely renewable. Other factors to be considered are the type and age of lights being replaced and the specifications of the upgraded lighting scheme. For new schemes, installation of Smart Systems to control LED lighting is recommended to provide added flexibility which may lead to reduced ongoing operating costs and carbon savings.

4.2.6. Research and innovation

Research and innovation are essential for advancing circular principles in transportation. Portugal has been involved in research projects related to sustainable and circular transportation solutions, which can lead to the development of new technologies and practices^{73,74,75}. Some examples are:

- Research on Sustainable Materials: Portuguese universities and research institutions engage in projects to develop new sustainable materials for vehicle manufacturing, such as lightweight and recyclable composites.
- Smart Transportation Solutions: Research and innovation in Portugal have led to the development of smart transportation systems that optimize route planning, reducing fuel consumption and environmental impact.
- Mobility and Energy Storage Research: Portuguese research institutions and universities have been involved in projects related to advanced energy storage solutions for electric vehicles (EVs). Research focuses on improving battery technology, developing smart charging infrastructure, and exploring second-life applications for EV batteries.
- Hydrogen Fuel Cell Technology: Research on hydrogen fuel cell technology and its application in various forms of transportation, such as buses and trains, has been ongoing. Portugal is looking into the use of hydrogen as an alternative clean energy source for transportation.
- Renewable Energy Integration: Research into integrating renewable energy sources, such as wind and solar, into transportation infrastructure. This includes exploring the use of renewable energy to power electric vehicles and rail systems.

In the field of railways, Portugal has been involved in several research and innovation projects aimed at enhancing the sustainability, efficiency, and effectiveness of its railway

⁷¹ Pardo-Bosch, F., Blanco, A., Sese, E., Ezcurra, F., Pujadas, P., Sustainable strategy for the implementation of energy efficient smart public lighting in urban areas: case study in San Sebastian. "Sustainable cities and society", 2022, vol. 76, p. 103454:1-103454:12.

⁷² State of the Nation 2020 Streetlighting Survey, UK Roads Liaison Group, CIHT ([sotn-report.pdf](https://www.ciht.org.uk/sotn-report.pdf) ([ciht.org.uk](https://www.ciht.org.uk)))

⁷³ EMEL, RESTART - Masterplan for Lisbon's Multimodal Mobility Hubs project, <https://www.emel.pt/pt/projectos/restart/>. Accessed 20 October 2023

⁷⁴ PERIN, SESAR - Single European Sky and ATM Research Joint Initiative, <https://pq-ue.ani.pt/h2020/sesar/>. Accessed 20 October 2023

⁷⁵ APDL, EALING - European flagship action for cold ironing in ports, <https://www.apdl.pt/media/2xufos2/ealing-2019-eu-tm-0234-s-cef.pdf>. Accessed 20 October 2023



transportation system. These projects cover various aspects of the railway sector, including infrastructure, rolling stock, energy management, and environmental impact reduction. Here are a few examples of research and innovation projects related to railways in Portugal^{76,77}:

- Eco-Train Project: The Eco-Train project focuses on developing more environmentally friendly and energy-efficient railway systems. It explores advanced technologies, such as regenerative braking and energy recovery, to reduce energy consumption and environmental impact. The project also investigates innovations in railway infrastructure design to optimize energy use.
- High-Speed Rail Innovation: Portugal has explored innovations in high-speed rail, including research into faster and more energy-efficient trains, as well as advanced signalling and control systems for high-speed routes.
- Passenger Experience and Accessibility: Projects related to passenger experience and accessibility aim to make railway travel more comfortable and inclusive. Innovations may include accessible train designs, real-time passenger information systems, and onboard services.
- Sustainable Freight Transport: Research projects are exploring ways to make freight transportation by rail more sustainable. This includes improvements in logistics, energy efficiency, and the development of intermodal transport solutions for freight.
- Noise and Emissions Reduction: Research into noise and emissions reduction focuses on mitigating the environmental impact of rail operations. Projects may involve the development of quieter trains, emission control systems, and the reduction of noise pollution along railway routes.

4.3. Performance measurement / KPIs

Key performance indicators (KPIs) are crucial to provide an ongoing measure and comparison of the performance or success of various strategies, methods, materials, technologies and innovations. KPIs can be used as a metric for many factors regarding circularity. Some developed KPIs are more strategic and focus on measuring organizational motivation and progress, while others are used to evaluate the success of particular projects, schemes or individual aspects within a project.

When developing or deciding on KPIs to be used within any particular context, it is important to clearly define measurements and input data used to evaluate and quantify the KPI value. The data required must be in line with the goal and objectives of the KPI set out by the individual organization or project.

In the most part within the road sector, there is currently little quantification of circularity and resource flows associated with ongoing maintenance, although some targets exist for reduction of waste. In relation to environmental evaluation, significant progress is being made in tracking carbon emissions. One of the main barriers in relation to circularity and resource efficiency currently is the lack of reliable, transparent data. For improvements in

⁷⁶ PIEP, EcoTrain, <https://www.piep.pt/ecotrain/>. Accessed 20 October 2023

⁷⁷ IP, Apresentação da Nova Linha de Alta Velocidade Porto - Lisboa, [Apresentação da Nova Linha de Alta Velocidade Porto - Lisboa | Infraestruturas de Portugal](#). Accessed 20 October 2023



this regard, collaboration between TI administrations and the supply chain is essential for the recording of data relating to production, consumption, recovery and disposal of material resources. This will facilitate the development and monitoring of suitable KPIs relating to circularity and will drive innovation to find solutions to improve resource efficiency⁷⁸.

Within the CERCOM project, an in-depth review of various published approaches to assess advances in circularity was conducted. As well as circularity indicators, other indicators of environmental impact were also included in the review. Table 4 presents the indicators that were identified and explored within the CERCOM report⁷⁸:

Table 4 Circularity indicators reviewed as part of CERCOM project

Indicator	Application
National Circularity Index (NCI)	Organizational or national level
Circulytics	Organizational or national level
Material Circularity Indicator (MCI)	Project level
Value-based Resource Efficiency (VRE) indicator	Project level
Platform CB'23	Framework at project level
Major Infrastructure – Resource Optimisation Group (MI-ROG)	Organization level or individual construction schemes
SCREEN guidelines	Project level
Environmental Cost Indicator (ECI)	Project level LCA
Development of a carbon indicator for bridges	Project level

In addition, published systems that are available to collate, organize and manage data for the purpose of producing KPIs were also investigated, and the following were examined⁷⁸:

- Format for transfer of data (EN 15942:2011)
- Material Passports and Building as Material Banks (BAMB)

The reviewed metrics were not all specific to TI and are mostly global indicators to provide an overall measure of CE and RE for a project or organization. Currently, many TI administrations are beginning to develop and implement CE strategies and the data to calculate complex KPI values is generally not available. The report summarized the importance of data collection by TI administrations and their supply chain to facilitate performance measurement and future development. It was also highlighted that for TI construction and maintenance it would be efficient to identify critical aspects or specific parts of the overall process, since in general, it is currently not practical to implement global indicators that encompass the entire supply chain. Further work is required to develop KPIs specifically addressing CE and enabling the transition to circularity and the quantification of outcomes to be monitored and reported. Some of the most commonly presented indicators currently monitored within TI administrations are presented in Table 5.

⁷⁸ CERCOM Deliverable D2.1 (2022), Good practice inventory of current systems and procurement methods ([Overview of Research Programmes Operations \(cedr.eu\)](#))



Platform CB'23 also recommends that indicators are not aggregated. At present, given the available data set and maturity regarding circularity indicators, it would be difficult to ensure each indicator is adequately weighted and considered as part of the analysis. For example, aggregated indicators may reduce the visibility of certain vital aspects related to circularity⁷⁸.

Table 5 Example of CE and environmental indicators currently used within TI

Category	Individual KPIs Identified within TI	Organization/Country
Circularity	Cumulated raw material expenditure ⁷⁹	Deutsche Bahn (DE)
	Materials used in construction ⁸⁰	National Highways, UK
	Percentage of non-hazardous waste recycled ⁸⁰	National Highways, UK
	Reduction in waste generation ⁸⁰	National Highways, UK
	Percentage of waste diverted from landfill ⁸⁰	National Highways, UK
	Material use per km of road built ⁸¹	National Highways, UK
	Percentage of materials used, available for next cycle, lost ⁸¹	Rijkswaterstaat (RWS), Netherlands
	Quantity of existing value used, value availability for next cycle, existing value left ⁸¹	Rijkswaterstaat (RWS), Netherlands
	Material circularity index ⁸¹	Rijkswaterstaat (RWS), Netherlands
	Reclaimed asphalt percentage used in construction ⁸¹	German Resource Efficiency Programme II
	Percentage of recycled aggregate used as concrete aggregate relative to the total volume of recycled construction materials ⁸¹	German Resource Efficiency Programme II
	Cumulative raw material consumption ⁸¹	German Resource Efficiency Programme II
	Raw material productivity ⁸¹	German Resource Efficiency Programme II
Environmental	Cumulated energy consumption in GJ ⁷⁹	Deutsche Bahn (DE)
	Global warming potential in tCO ₂ ⁷⁹	Deutsche Bahn (DE)
	Cumulative energy expenditure ⁸¹	German Resource Efficiency Programme II
	Environmental Cost Indicator (ECI) ⁷⁹	ProRail; Rijkswaterstaat (RWS)

⁷⁹ [Circular practices in the railway and ways forward - REUSE Project final Report \(uic.org\)](#)

⁸⁰ CERCOM Deliverable D4.3 (2023), Case study III – NRAs Strategic Approach to Transitioning to CE ([Overview of Research Programmes Operations \(cedr.eu\)](#))

⁸¹ Mantalovas, K.; Di Mino, G.; Jimenez Del Barco Carrion, A.; Keijzer, E.; Kalman, B.; Parry, T.; Lo Presti, D. European National Road Authorities and Circular Economy: An Insight into Their Approaches. Sustainability 2020, 12, 7160. <https://doi.org/10.3390/su12177160>



In addition, examples of proposed Green Public Procurement criteria relating to resource efficient road design, construction and maintenance are⁸²:

- Recycled content.
- Recyclability of tar-containing asphalt.
- Re-use and/ or recycling of excavated materials on-site/off-site and materials diverted from landfill.
- Recycling and/or re-use of demolition waste.
- Use of low temperature binder.
- Material transportation.
- Life cycle performance.

Although it is recommended that productivity-based metrics form a good basis for a measure of CE performance, while standardized performance measures are being developed and as sufficient data is collated, an effective alternative is the use of impact-based metrics, such as those presented in Table 5. However, it is acknowledged that not all indicators provide context to the impacts generated, the value created or the level of utility. In such cases, a measure of Residual Value may be useful, particularly with respect to maintenance activities, where it could be shown that preventative maintenance is an efficient option by increasing the retained value of the existing asset⁷⁸.

As part of the CERCOM project, various practical case studies covering a range of road maintenance options were carried out to demonstrate and validate the use of the developed Risk-Base Analysis Framework⁸³. Through implementation of the case studies, it was highlighted that although mass-based circularity indicators (e.g., MCI) are beneficial in quantifying the circularity potential of different maintenance scenarios, there are inherent limitations. Value based indicators can be useful to quantify both the quality and quantity of materials to evaluate the CE potential and end of life strategies for pavements. For the implemented case studies, the use of various mass/value-based indicators was explored as a means to determine circularity indicators. The assumptions and limitations of two approaches were evaluated and it was concluded that⁸³:

“The value-based indicator seems to be a promising alternative to the conventional MCI method as it considers the quality of the recycled materials along with the quantity, while also taking into account the environmental, economic, and social aspects.”

The value-based indicator, called the Circular Economy Index (CEI), is a more simplified approach compared to the MCI, lending itself to implementation within TI while more comprehensive datasets are developed. However, it was essential to modify the CEI for

⁸² Garbarino E., Rodriguez Quintero R., Donatello S., Gama Caldas M. and Wolf O.; 2016; Revision of Green Public Procurement Criteria for Road Design, Construction and Maintenance. Technical report and criteria proposal; EUR 28013 EN; doi:10.2791/683567

⁸³ CERCOM Deliverable D4.1 & D4.2 (2023), Case studies I & II – Protocol and Results ([Overview of Research Programmes Operations \(cedr.eu\)](#))



implementation within the CERCOM case studies to cover a broad range of pavement maintenance and life extension alternatives, such as pavement rejuvenation and surface treatment⁸³. The adapted method is only suitable when assets have remaining value at the end of life.

It is important to achieve some form of consistency in the area of performance measurements and indicators to allow the supply chain to adapt and respond, and to ensure efficient collation of data to facilitate and enhance further progress⁸⁰. It is encouraging to see the increased development and use of LCA tools and carbon calculation tools being recommended or mandatory as part of public procurement policies in many European countries (e.g., DuboCalc (Netherlands), asPECT (UK), TII carbon tool (Ireland)). Carbon neutrality is a priority for many European countries and TI administrations and provides a good starting point and frame of reference for the establishment and implementation of CE principles⁷⁸. The Environmental Cost Indicator (ECI) is used within the DuboCalc tool to provide a single score indicator of the overall environmental cost of a project. It was first adopted by the Dutch roads authority (RWS) but has since been adopted by Dutch railway operators⁸⁴.

Level(s) is a European framework for sustainable building design and performance⁸⁵. Within the framework six macro-objectives and sixteen indicators were established to provide a means to assess and report key aspects of sustainability over the life cycle of a building. The indicators defined align with EU policy objectives to provide a common language to strengthen the sustainability of Europe's buildings and are outlined in Table 6.

Table 6 Outline of Level(s) macro-objectives and indicators⁸⁶

Macro-Objectives	Indicators
Greenhouse gas emissions (life cycle)	Use phase energy performance (kWh/m ² /yr) Life cycle Global Warming Potential (CO ₂ eq./m ² /yr)
Resource efficient and circular material life cycles	Bill of quantities, materials and lifespans Construction & Demolition waste and materials Design for adaptability and renovation Design for deconstruction, reuse and recycling
Efficient use of water resources	Use stage water consumption (m ³ /occupant/yr)
Healthy and comfortable spaces	Indoor air quality Time outside of thermal comfort range Lighting and visual comfort Acoustics and protection against noise
Adaption and resilience to climate change	Protection of occupier health and thermal comfort Increased risk of extreme weather Sustainable drainage
Optimized life cycle cost and value	Life cycle costs (€/m ² /yr) Value creation and risk factors

⁸⁴ [Circular practices in the railway and ways forward - REUSE Project final Report \(uic.org\)](#)

⁸⁵ [Level\(s\) \(europa.eu\)](#)

⁸⁶ [How does Level\(s\) work? \(europa.eu\)](#)



The criteria for each of the 16 indicators varies depending on the Level selected for assessment. There are 3 defined levels:

- Level 1 Conceptual design.
- Level 2 Detailed design and construction.
- Level 3 As-built and in-use.

Using existing standards, the framework can be used at different stages of a building's lifecycle and can be used by various stakeholders throughout the process. The software developed to apply the framework is open source and freely available. While the indicators are not all directly applicable to TI, the framework provides a robust, verified approach to assessing sustainability and circularity of schemes across their life cycle.

4.4. Review of European standards and trends in circularity

Standards cover various aspects relating to the implementation of circularity in Europe. Particular standards are focused specifically on organizational culture and how to promote CE within organizations. Discussion and examples in this regard are provided in Section 5.1.1.

Within this section, various technical standards relating to materials, design and waste management are reviewed. Specific standards in numerous European countries are reviewed to provide an overview of the trends towards circularity. Although some standards are focused on carbon reduction, many of the practices and procedures within the standards encompass CE principles.

4.4.1. PAS 2080:2023 Carbon management in buildings and infrastructure

PAS 2080 is a global standard developed for the purpose of designing out carbon in all sectors of building and infrastructure, through more intelligent design, construction and use. The framework looks at the whole value chain and ensures the transparent quantification of carbon at key points in infrastructure delivery, facilitating collation and sharing of data along various stages of a project. The original version was published in 2016, and the updated version was published in 2023, including emerging approaches, including net-zero, the role of infrastructure as a system and carbon offsetting⁸⁷. The standard targets carbon management, management of data (reporting, quantification, inclusion in BIM, etc.), management of various sources of carbon and promoting whole life carbon reductions⁸⁸.

The following targets are aimed at reducing carbon emissions but also supporting CE principles⁸⁸:

- Amount of waste generated and treated
- Percentage of recycled content used versus virgin material
- Percentage of biological material used

⁸⁷ ICE, Financing low-carbon infrastructure: a practical guide for civil engineers, 2022 ([Financing low-carbon infrastructure | Institution of Civil Engineers \(ICE\)](#))

⁸⁸ CERCOM Deliverable D2.1 (2022), Good practice inventory of current systems and procurement methods ([Overview of Research Programmes Operations \(cedr.eu\)](#))



4.4.2. UK Design Manual for Roads and Bridges

There are various standards within the UK Design Manual for Roads and Bridges (DMRB) that encompass CE principles. They outline requirements to follow resource efficient approaches and manage waste through sustainable development, and evidence of applicability is clear through environmental statements submitted for current projects. The importance of adopting circular principles and good design early on in the process is acknowledged⁸⁰. The standards of particular relevance to CE are:

- GG103 – Introduction and general requirements for sustainable development and design. This standard introduces the concept of sustainable development and enforces CE principles by requiring that *“the design be resource efficient and reflect a circular approach to the use of materials”*⁸⁸.
- LA110 – Material assets and waste. The scope of this standard involves the consumption and use of material assets and the disposal and recovery of waste. It includes requirements for the environmental assessment to demonstrate how the project design has adopted the waste management hierarchy (preference for avoidance, above re-use, recycling, etc.). There is also a requirement to identify potential opportunities for environmental enhancement and report on material assets and treatment of waste for the construction phase and first year of operation⁸⁸.

4.4.3. Irish National standards

In Ireland, updates were made to the pavement design standard (DN-PAV-03021 Analytic Pavement & Foundation Design) in 2022 to allow design to be customized to the local environment and performance characteristics of locally available materials. This is done using the developed tool, Irish Analytical Pavement Design Method (IADPM)⁸⁰. This updated standard facilitates resource efficiency and encourages the development of innovative materials and construction methods.

Further to this, certain standards have been adapted to allow performance-based specifications. An example is the introduction of performance measures in the pavement specification (CC-SPW-00900 Road Pavements – Bituminous Materials) in 2022. The amendments facilitate the use of high-quality, low temperature materials with increasing recycled content and demonstrate ways that updated standards and specification can encourage change and increased circularity and resource efficiency within the supply chain.

It is acknowledged that this may lead to an increase in technical performance risk while the transition from conservative methods towards more innovative approaches are established. There is more emphasis on preserving existing pavements using less materials and/or secondary materials and on compiling robust data. However, the IADPM is an established resource which provides an approach based on technical analysis to manage and minimize this risk⁸⁰.



4.4.4. Spanish National standards

In Spain, the Circular Order OC 2/2023 on the reuse of layers of bituminous roads and pavements of the Ministry of Transport, Mobility and Urban Agenda (MITMA) reviews and updates the content of the previous OC 40/2017 related to the recycling of road and bituminous pavements⁸⁹. The goal is to expand its field of application and make it imperative to reuse the pavements as a standard solution and to ensure that road projects are directed towards sustainable solutions that contribute to reducing the environmental impact during all stages of the useful life cycle of roads and bituminous pavements: construction, use, and end-of-life.

4.4.5. Portugal - National Laboratory of Civil Engineering (LNEC) specifications

Following the introduction of CDW laws in Portugal in 2008 (Section 2.1.2), various specifications were developed by the National Laboratory of Civil Engineering (LNEC)⁹⁰ to guide the circularity within the construction sector:

- E471 (2009) - Guide for the use of coarse recycled aggregates in concrete. This document establishes the minimum requirements that the coarse recycled aggregates covered by EN 12620 must comply with in order to be used in concrete.
- E472 (2009) - Guide for the production of recycled hot mix asphalt. This document classifies reclaimed asphalt materials covered by EN 13108-8 and provides guidelines for their use in hot mix recycled asphalt.
- E473 (2009) - Guide for the use of recycled aggregates in unbound pavement layers. This document establishes the requirements that recycled aggregates covered by EN 13242+A1 and EN 13285 must comply with in order to be used in unbound sub-base and base pavement layers.
- E474 (2009) - Guide for the use of recycled materials coming from construction and demolition waste in embankment and capping layer of transport infrastructures. This document establishes the minimum requirements that construction and demolition waste must comply with in order to be used in embankment and capping layer of transport infrastructures.

New regulations on these topics were introduced in 2016, with the development of the National Strategy for Green Public Procurement (ENCPE) RCM no. 38/2016⁹¹, aimed to involve public bodies in a process that would encourage the practice of green purchasing, encouraging more environmental awareness with suppliers and service. Simultaneous, a new list of specifications were developed by LNEC⁹⁰:

- E483 (2016) - Guide for the use of recycled aggregates from reclaimed asphalt for unbound road pavement layers. The specification provides recommendations and

⁸⁹ https://www.mitma.es/recursos_mfom/comodin/recursos/oc_2023_02_reutilizacion_de_capas_de_firmes_0.pdf

⁹⁰ LNEC, Current LNEC Specifications, <https://www.lnec.pt/pt/servicos/normalizacao-e-regulamentacao/especificacoes-lnec/especificacoes-lnec-em-vigor/>. Accessed 20 October 2023

⁹¹ RCM No. 30/16 of 29 July of the Presidency of the Council of Ministers. Diário da República: I série, No 145 (2006). Accessed 20 October 2023



defines minimum requirements for the use of recycled aggregates with proportions of reclaimed asphalt greater than 30 %, covered by EN 13242+A1, in unbound pavement layers (base and sub-base), taking also into consideration EN 13285. The recycled aggregates referred to in this Specification come from maintenance, rehabilitation and demolition of road and airport pavements and other paved areas. These aggregates consist of milled or crushed pavement layers and may be applied singly or in combination with recycled aggregates or with natural aggregates.

- E484 (2016) - Guide for the use of materials resulting from construction and demolition waste in rural and forest roads. The specification provides recommendations and defines the minimum requirements that construction and demolition waste must comply with in order to be used in rural and forest roads. This construction and demolition waste comes from construction works, rehabilitation and demolition of buildings, transport infrastructures or other civil engineering works.
- E485 (2016) - Guide for the use of materials resulting from construction and demolition waste in backfill of trenches. The specification provides recommendations and defines minimum requirements for the use of materials coming from construction and demolition waste in backfill of trenches. This construction and demolition waste comes from construction works, rehabilitation and demolition of buildings, transport infrastructures or other civil engineering works.
- E482 – 2021 (2020) - Guide for the use of cold asphalt mixes for quick patching of road pavements. This technical specification presents recommendations and defines the minimum requirements applicable to cold asphalt mixes for the quick patching of road pavements.

4.4.6. Recommendations

The goal is to revise existing standards and develop new standards to adapt design, construction and maintenance principles to facilitate the use of recycled and secondary materials and mitigate barriers resulting from current standards. This would include the development of a system for certification of CE products considering the cradle-to-cradle philosophy to encourage repair, refurbishment and/or re-use at end of life. Quantifying and managing this additional risk will facilitate the adaptation of standards to allow for the use of variable quality secondary resources which do not comply with the material testing requirements established for virgin materials.

4.5. Procurement and supply chain

Procurement can be an effective means to communicate and encourage circularity ambitions by tailoring the specification and bid evaluation process to achieve these goals. Within tender documents, bidders can be requested to demonstrate, for example, how materials and/or waste will be managed using CE principles. Bids can then be evaluated based on specified weights to include circularity indicators of various schemes or strategies that are proposed.



As knowledge and ambition regarding sustainability, carbon neutrality and circularity have grown, various guidance and support documents have been published to drive the necessary changes under the following headings:

- Sustainable public procurement.
- Green public procurement.
- Circular public procurement.

The motivation and distinctions between the various headings will be outlined below, followed by national examples of implementation.

4.5.1. Sustainable public procurement (SPP)

Procurement can be a very effective driver to enforce change and progression towards more sustainable practices. It allows for transparency and gives organizations the opportunity to encourage the supply chain to respond with more sustainable and/or innovative solutions. This can help to build confidence within the open markets and encourage collaboration between organizations⁸⁸. TI administrations, as large public bodies, have the power to facilitate and drive more sustainable development through their procurement procedures. As well as offering financial efficiency, sustainable procurement provides a means to manage demand and resources, ensure ongoing contract management and coordination with the supply chain. Sustainable procurement aims to achieve an appropriate balance between the following three themes at all stages in the procurement process⁹²:

- Economic-
- Social.
- Environmental.

Since the recognition of the need to mitigate climate change, protect the environment and reduce emissions, there have been various EU and national guidelines and policies to facilitate the introduction of sustainable procurement to achieve environmental goals, value for money and benefits related to social criteria. The first international standard published on this basis was ISO 20400 in 2017.

Some national bodies have published supporting standards and guidelines to facilitate organizations in implementing public procurement practices. For example, the British Standards Institution (BSI) published the following set of standards to provide guidance to organizations in the implementation of sustainable procurement procedures⁸⁸:

- BS ISO 20400: 2017, Sustainable procurement – Guidance
- BS ISO 44001: 2017, Collaborative business relationship management systems – Requirements and framework
- BS ISO 44002: 2019 Collaborative business relationship management systems – Guide to implementing BS ISO 44001

⁹² [gov.ie - Sustainable Public Procurement \(www.gov.ie\)](https://www.gov.ie/en/publications-and-resources/publication/sustainable-public-procurement/)



The Institution of Civil Engineers (ICE) produced a guidance document to provide a framework for inclusion of net-zero targets into procurement processes and associated contracts. Although the document is largely motivated by net-zero targets, procedures outlined impact on other sustainability and circularity issues. The framework provides guidance in tabular form through the various procurement and contract stages of a project, with information provided for organizations with varying levels of expertise⁹³.

TI administrations within Europe are at different stages of advancement in terms of sustainable procurement and it continues to be an ongoing process of development to meet the evolving global and national challenges.

4.5.2. Green public procurement (GPP)

Green Public Procurement is an initiative started by the European Commission (EC) to encourage governments to promote green procurement and is defined as⁹⁴:

“a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured.”

A GPP guidance document was published by the EC Joint Research Centre in 2016 to provide specific guidance for road design construction and maintenance⁹⁵. The document is structured to provide guidance for each distinct phase of procurement activity⁹⁵:

- Preliminary scoping and feasibility
- Detailed design and performance requirements
- Construction and major extensions
- Use of the road
- Maintenance and operation
- End of life (i.e., road decommissioning)

The aim is to facilitate the procurement of environmentally improved roads. Within the document, there are two sets of criteria provided to cater for varying levels of maturity and/or ambition.

- A set of Core criteria - designed to allow easy application of GPP and keep associated administrative costs to a minimum. This prioritises key aspects of environmental performance of a product.
- A set of Comprehensive criteria – the goal is to take account of a wider range and more complex or advanced aspects of environmental performance. It is aimed at authorities who are ambitious and are striving to advance maturity in terms of environmental and innovation goals.

⁹³ Institution of Civil Engineers (ICE), Procurement and Contract Guidance on Delivering Net-Zero Carbon, 2022.

⁹⁴ [Green Public Procurement \(europa.eu\)](https://ec.europa.eu/euro-observatory/en/green-public-procurement)

⁹⁵ Garbarino E., Rodríguez Quintero R., Donatello S., Gama Caldas M. and Wolf O.; 2016; Revision of Green Public Procurement Criteria for Road Design, Construction and Maintenance. Technical report and criteria proposal; EUR 28013 EN; doi:10.2791/683567



Taking the proportion of recycled content as an example, core criteria may specify a minimum of 15%, whereas comprehensive criteria would specify a minimum of 30%. Core criteria specifies individual indicators such as carbon emissions, whereas Comprehensive criteria may require a full life cycle analysis (LCA).

4.5.3. Circular public procurement (CPP)

In most cases, TI administrations in Europe are at an early stage in implementing specific circular procurement policies. Most policies still support the traditional linear production model⁸⁴. However, circular procurement guidelines have been published which contain established criteria such as environmental impact criteria and assessment of tenders using most economically advantageous tenders (MEAT) which inherently encompass particular CE principles. For further progress, it is recommended that procurement practices move away from traditional approaches, where cost is assigned the most significant rank, towards performance-based procurement criteria, where a higher rank is placed on RE and CE criteria (e.g., life extension, optimization of lifespan, material/product utility and waste minimization)⁸⁸. When CE criteria are embedded into functional specifications within tenders, monitoring should be put in place to evaluate progress and track success, or lessons learned. In addition, successful circular procurement requires collaboration between various stakeholders within TI. An established long-term relationship between parties is more likely to encourage circular use and resource efficiency going forward⁸⁴.

4.5.4. National examples

UK

In the UK, standards are being revised to address the facilitation of CE. Currently, standards permit a limited percentage of RAP, however, the Departure from Standards mechanism allows the supply chain to propose alternative approaches and methods for approval⁸⁸.

‘Pathfinder projects’ were also established by National Highways to develop and record the application of circular principles and to identify barriers/opportunities, increase awareness and build knowledge to enable CE to become an integral part of procurement.

The Major Infrastructure – Resource Optimization Group (MI-ROG) published a white paper in 2016 with guidelines on embedding circular economy principles into infrastructure operator procurement activities. The following were identified as significant drivers to achieve progress towards circularity within the procurement process⁹⁶:

- Begin discussing CE motivation and criteria from the outset of the infrastructure scheme.
- Take a consistent approach to CE procurement for major infrastructure projects to drive the market.
- The development of frameworks to support innovation that support CE, where risks are shared while new materials or approaches are integrated.

⁹⁶ MI-ROG (2016) Embedding circular economy principles into infrastructure operator procurement activities. White paper. Downloaded from [Embedding-Circular-Economy-into-Procurement-MI-ROG-White-paper_October-2016-1.pdf \(aecom.com\)](#).



- Collaboration between various suppliers and stakeholders throughout the supply chain across various themes to foster relationships to facilitate resource efficiency within procurement.
- Increased cooperation and communication between procurement teams, project managers, designers and the supply chain throughout a project will also enhance integration of circularity.
- Develop CE business models and working groups to identify key benefits to inform focused action plans.
- Evaluation of 'whole life value' of materials throughout commissioning, maintenance and disposal rather than just the costs.

Additional guidance is provided for questions and criteria that can be included in the procurement process to help transport operators rank and select suitable suppliers.

Ireland

A National Action Plan for GPP was published in Ireland in 2012 to provide guidance on the integration of environmental factors into the procurement process to aid sustainable development⁹⁷. In 2019, the Department of Public Expenditure and Reform published a document instructing government departments to use green criteria in procurement to promote the use of environmental and social considerations in public procurement⁹⁷. To aid communication and foster growth in the area of GPP, the Office of Government Procurement (OGP) led the development of 'GPP Criteria Search'. This is an online search tool that can be used to rapidly find, select, and download the Irish GPP criteria relevant to a specific procurement project⁹⁸.

TII have adopted an internal Circular Economy Action Plan, with procurement one of the key aspects addressed within the document. Development of green procurement practice including life cycle analysis is ongoing with updated procedures in 2023 to make Environmental Project Declarations (EPDs) a requirement for hot mix asphalt⁸⁰. In addition, certain standards have been adapted to allow performance-based specifications. An example is the specification for bituminous pavement materials, which has moved from recipe to performance specification in order to facilitate the use of high-quality, low temperature materials with increasing recycled content. Based on the updated specification, a case study was conducted to evaluate the impact of various potential measures. By using cold mix asphalt and 80% RAP, the case study indicated a 41% reduction of embodied carbon when compared with a traditional mix⁸⁰.

The goal is that updated standards and specifications within procurement can drive change within the supply chain. Supply chain collaboration also is recognized as a key enabler, with various stakeholders identified (e.g., including national standards authority, environmental protection agency, technical designers within TII, environmental product declaration working groups etc.).

It was also noted that although specifications allow lower temperature asphalt, it appears that in general, designers are reluctant to specify these newer methods. In some cases, the

⁹⁷ [gov.ie - Sustainable Public Procurement \(www.gov.ie\)](https://www.gov.ie/en/publications/2019-06-27-sustainable-public-procurement/)

⁹⁸ [gov.ie - Green Public Procurement \(www.gov.ie\)](https://www.gov.ie/en/publications/2019-06-27-sustainable-public-procurement/)



contractors are driving change and requesting the use of more innovative methods due to the economic benefits of operating at lower temperatures. It is envisaged that this will increase as communication of success builds confidence in new approaches⁸⁰.

Netherlands

In 2010 the Dutch House of Commons set an ambitious target for all public government authorities to achieve sustainable procurement by 2015, making the Netherlands the first European country to formalise sustainable public procurement procedures. This led the Department of Public Works of the Ministry of Infrastructure and the Environment, Rijkswaterstaat (RWS) to adapt procurement procedures and work towards implementing functional specifications to facilitate innovation and more sustainable design, construction and maintenance of road infrastructure. Developments towards functional-based specifications standards are on-going and RWS has implemented tools that are used by all tenderers to measure CO₂ emissions and environmental impacts (the CO₂ performance ladder and DuboCalc). This forms the assessment criteria for assessing the sustainable aspect of tenders during evaluation and ranking⁹⁹. RWS use the Most Economically Advantageous Tender (MEAT) method to evaluate and rank tenders, which takes account of the quantification of CO₂ and environmental impacts.

Portugal

Public procurement policies play a significant role in promoting circular principles. Portugal has been encouraging green public procurement, which includes considering the environmental impact of transportation options when making decisions on government vehicle fleets and transportation services¹⁰⁰.

- **Government Fleet Upgrades**: Public institutions in Portugal have started to transition their vehicle fleets to more environmentally friendly options, such as electric or hybrid vehicles, and those with lower emissions.
- **Sustainable Transport Services**: Government contracts for transportation services (e.g., for public employees or school transportation) may include requirements for service providers to use eco-friendly vehicles and adhere to sustainability criteria.

Belgium

The Belgian Federal Institute for Sustainable Development (IFDD) has developed a sustainable procurement guide that describes technical sustainability criteria to be included in the purchase specifications of supplies and services¹⁰¹. In addition, the Belgian Transport Research Centre (CRR) has developed a series of sustainability indicators of an environmental, social and economic nature, with the aim of being included in tenders with an easy, simple and objective methodology¹⁰².

⁹⁹ M. Lamb, H. Viner, V. Ramdas, L. Connolly and E. Sheils. Carbon Neutrality of the Road Sector. A PIARC Special Report, 2022.

¹⁰⁰ RCM No. 30/16 of 29 July of the Presidency of the Council of Ministers. Diário da República: I série, No 145 (2006). Accessed 20 October 2023

¹⁰¹ Institut fédéral pour le Développement durable (IFDD), "Guide des Achats durables," 23 September 2003. [Online]. Available: <https://guidedesachatsdurables.be/fr>. [Accessed 3 May 2023].

¹⁰² Center Recherches Routières (CRR), "Ensemble pour des routes durables," 12 April 2018. [Online]. Available: <https://brrc.be/fr>. [Accessed 3 May 2023].



Spain

A National Action Plan for Green Public Procurement (GPP) was published in 2019 ‘Green Public Procurement Plan of the General Administration of the State, its Autonomous Organizations and the Managing Entities of Social Security (2018-2025)’. The Plan responds to the need to incorporate ecological criteria in public procurement, which will allow administrations, in the development of their activity, to promote and contribute to the objectives of economic and environmental sustainability. Its main targets are:

- Promote the acquisition by the public administration of goods, works and services with the lowest environmental impact.
- Serve as an instrument to promote the Spanish Circular Economy Strategy.
- Guarantee a more rational and economical use of public funds.
- Promote environmental clauses in public procurement.
- Publicize the possibilities offered by the legal framework of green public procurement.

The plan contains, in its Annex, some standards and specifications for the design, construction and maintenance of roads, such as¹⁰³:

- Reduction of energy consumption in the manufacturing and execution of work units (for example, using semi-hot, warm, or cold bituminous mixes, etc.).
- Design, specification, and management of the work to optimize the on-site reuse of excavated materials and soil (including topsoil), maximize the reuse or recycling of construction and demolition waste, tires and waste from other industrial processes and use construction materials with a high content of recycled or reused material, including secondary products.

In addition, in 2022, CEDEX launched a publication on the ‘State of the Art on Green Public Procurement of Roads’, which summarizes the plans, national strategies, and related regulations. Different ecological public procurement criteria have also been studied focused on the construction and maintenance of roads, mainly covering road surfaces and pavements, as well as raw materials, such as cement, binder, and aggregates. Others such as earthworks, fauna and the natural environment have also been considered¹⁰⁴.

¹⁰³ <https://www.miteco.gob.es/es/ministerio/planes-estrategias/plan-de-contratacion-publica-ecologica.html>

¹⁰⁴ <https://www.cedex.es/centros-laboratorios/centro-estudios-transporte-cet/proyectos/monografia-cedex-estado-arte-sobre-contratacion-publica-ecologica-carreteras>



5. Identification of the economic, regulatory and incentivization framework

5.1. Organizational culture

One of the key motivators for employees to adopt circular principles is strong leadership and organizational culture. This facilitates knowledge sharing and collaboration between various teams within an organization to develop and/or update products, specifications and business models. This can then extend to other areas or companies within the supply chain and promote the transition from a linear to a circular economy. This section briefly outlines various standards and initiatives which encourage an organizational culture which promotes circularity¹⁰⁵.

5.1.1. Standards related to organizational culture

In 2017, the United Kingdom was the first country in Europe to introduce a standard specifically related to the implementation of CE within organizations, called *BS 8001:2017 Framework for implementing the principles of the circular economy in organisations – guide*¹⁰⁶. While not mandatory, the aim was to provide a flexible framework to facilitate organizations implement more circular practices through¹⁰⁵:

- Improved work practices
- Production of more circular products and/or services
- Amendment or redesign of business models

The document provides guidance for organizations with varying levels of knowledge or maturity and presents a maturity model with 8 stages for organizations to monitor performance and progression.

In 2018, the French Association for Standardization (ANFOR) published a voluntary standard called *XP X 30-901 CE project management system - Requirements and guidelines*¹⁰⁶. The standard proposes a matrix framework covering various aspects of both sustainable development and circular economy which should be considered¹⁰⁷. This guideline allows companies to identify areas for improvement and accelerate the shift towards a more circular economy.

¹⁰⁵ CERCOM Deliverable D2.1 (2022), Good practice inventory of current systems and procurement methods ([Overview of Research Programmes Operations \(cedr.eu\)](#))

¹⁰⁶ Mantalovas, K.; Di Mino, G.; Jimenez Del Barco Carrion, A.; Keijzer, E.; Kalman, B.; Parry, T.; Lo Presti, D. European National Road Authorities and Circular Economy: An Insight into Their Approaches. Sustainability 2020, 12, 7160. <https://doi.org/10.3390/su12177160>

¹⁰⁷ [circular_economy_and_voluntary_standard.pdf \(europa.eu\)](#)



The development of these standards in the UK and France directly related to CE led to the establishment of a technical committee within the International Organization for Standardization (ISO TC 323). The goal is to inform and enhance the development of international standards for implementation by organizations with motivation to implement CE practices¹⁰⁶.

5.1.2. Platform CB'23

In 2019, Platform CB'23, a Dutch initiative within the construction sector, published a framework for assessing circularity in buildings and civil engineering in the Netherlands. Stakeholders from across the construction industry sector were gathered to work together to support a transition to a circular economy. Various aspects were examined, including¹⁰⁵:

- Terminology and definitions.
- Review of existing frameworks.
- Methodology for measuring circularity.
- Material passports.
- Data sharing.

The requirement for uniformity across the sector was identified and a framework to quantify circularity at a project level was proposed.

As part of the initiative, procedures were developed to allow innovative products and procedures that are not currently covered under existing standards to be benchmarked and approved.

5.1.3. CinderOSS

CinderOSS (CINDERELA One Stop Shop)¹⁰⁸ is a service provided through an online platform and offline services. The initial model was developed in the H2020 project CINDERELA as a support for creation of urban circular construction business models helping companies in the construction sector that have a motivation to implement circular business models in their organization structure. The platform provides information about circular business models that function as best practice, information about legal / stimulating aspects that might be of added value when implementing circularity, an overview of the state-of-the-art in circular construction (e.g. research papers that display innovative measures could be of use for companies active in the construction sector), EU and MS legislation procedures, products, financial programmes / instruments, projects, etc. It also includes a community platform, business finder, access to offline services, BIM libraries for elements with circular content, an E-learning platform and on-line marketplace. It is available partly in English, Slovenian, Italian, Spanish and Dutch.

The platform is managed by ZAG with IT support from Opencontent (Italy). In LIASION new content will be uploaded with circularity models in transport infrastructure which will serve

¹⁰⁸ <https://cindeross.cinderela.eu/>



as an entry point for an online marketplace and business finder. The tool is also being optimised in a complementary project to LIASION. This project, ReBuilt, is an Interreg Central Europe project on circular and digital construction.

5.1.4. CERCOM maturity model

As part of the CEDR funded CERCOM project on circular economy in road construction and maintenance, a maturity model framework was developed to allow organizations to assess maturity and analyse steps that could be taken to progress towards a higher maturity in terms of circularity.

For 7 key attributes of Resource Efficiency and Circular Economy (RECE) within an organization, three stages of maturity were identified and outlined, with each stage split into three distinct stages¹⁰⁵:

- Engaging in transition to RECE (stages 1 to 3 inclusive).
- Early stages of practicing RECE (stages 4 to 6 inclusive).
- Active development of RECE (stages 7 to 9 inclusive).

The 7 key attributes were:

- CE ambition.
- Embedding CE.
- Performance monitoring (KPIs).
- Standards.
- Supply chain.
- Business models.
- Circular procurement.

The developed matrix allows organizations to assess the step change in maturity from initial stage of transition to full active deployment of RECE and provides a tool to facilitate planning, training and actions required to move along the various maturity stages¹⁰⁵.

Based on the reviews and findings of CERCOM, the following aspects were identified as good practice to advance circularity in the context of organizational culture¹⁰⁵:

- Clear direction set at director level and communication to all levels of staff.
- Establish baseline in terms of organizational maturity.
- Collect data.
- Commit to action.
- Set targets and monitor progress.
- Involve the supply chain on the journey.
- Consider bonus schemes / incentives for achieving environmental targets.



5.2. Regulatory and incentivization frameworks to foster circularity in TI

5.2.1. Impact of regulatory frameworks

European and national policies and strategies regarding the implementation of circularity are outlined in Section 2.1.2 and strategies and incentives implemented by TI administrations to facilitate and motivate progression regarding circularity are discussed in Section 4.1. It has been demonstrated that these regulations and policies have had varying degrees of success in implementing change towards a circular economy across various European nations. Procurement laws are also an effective driver of change within public bodies, as demonstrated in the Netherlands (Section 4.5.4). Adding to areas discussed earlier in the document, additional aspects regarding regulatory frameworks are outlined below.

- It was highlighted in the ICE publication, *Financing Low-Carbon Infrastructure*¹⁰⁹, how planning laws and regulations are having a significant impact on current infrastructure projects, with many abandoned at planning stage because they don't adequately address the climate change risk and the net-zero targets. This can also affect the securing of finance as financiers are aware of current carbon targets and will take a projects' credentials into account¹⁰⁹. Civil engineers have a responsibility to embrace change and quantify risk associated with new technologies and methods to facilitate the integration of low-carbon designs.
- The increased uptake of EPDs should have the effect of reducing the environmental burden associated with products and services. EPDs follow a standardized format outlined in standard EN 15942:2011 (Sustainability of construction works. Environmental product declarations. Communication format business-to-business) according to EN 15804:2012 (Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products). The standards set out a framework for providing quantified environmental information for construction products and services, ensuring a transparent and standardized approach for assessing options that provide the least negative impact on the environment. While not directly motivated by increasing circularity, this standardized approach facilitates collation of environmental life cycle data and the development of more sustainable methodologies and designs. EPDs have a role to play in maturing and enhancing the framework to enhance circular approaches¹⁰⁵.
- In the Netherlands, one of the main drivers for adopting circular principles within TI projects is the maturity of the legal framework regarding construction and demolition waste management¹⁰⁵, which are national laws implementing EU directive 2008/98/EG. It has had the effect of reducing premature asset demolition, increasing durability of built assets and design of products and services that can be reused, repaired, recycled or recovered. Austria and Germany have similar national guidelines and internal planning manuals which follow the EU directive¹⁰⁶.

¹⁰⁹ ICE, Financing low-carbon infrastructure: a practical guide for civil engineers, 2022 ([Financing low-carbon infrastructure | Institution of Civil Engineers \(ICE\)](#))



5.2.2. Additional economic incentives

As well as the regulatory guidance and targets outlined, there are various additional incentives and frameworks that have a role in the adoption of circular principles within TI.

5.2.2.1. *Material passports/REM*

Material passports can be a very useful tool to support the transition to circular economy. They are digital data sets that are emerging within the building industry to collate and store information regarding the CE characteristics of products, materials or components. The goal is to encourage recovery and reuse of materials within the supply chain. They provide a means to collect and present data related to material inventories to improve the efficiency of material circulation. Using these methods as part of flagship or pathfinder projects can increase awareness and encourage the flow of information regarding material use and reuse¹⁰⁵.

Following a similar approach, a resource exchange mechanism was established within National Highways in the UK to facilitate circularity and protect the use of virgin materials. It is currently being developed and trialled as part of the Pathfinder projects, the goal is to provide up to date information on various resources available from ongoing projects to encourage reuse of materials between schemes and minimize the need for transport and storage of surplus materials¹¹⁰.

5.2.2.2. *Tax breaks and Carbon Tax*

Energy Conservation Measures (ECMs) are implemented by TI administrators to reduce carbon emissions. In many cases the financial cost of implementing these measures can outweigh the benefits of the associated carbon reduction. Many governments have therefore introduced tax incentives and/or financial models to promote carbon reductions and make these initiatives feasible⁹⁹.

Carbon pricing is another financial initiative aimed at reducing carbon. The most common forms of implementing carbon pricing are Carbon Tax and Emissions Trading Systems (ETS). The goal is to transfer the cost of external damage (e.g., environmental, economic and social) from Greenhouse Gas Emissions (GHGs) to the industries causing these emissions through pricing frameworks. This is usually in the form of a cost based on the quantity of CO₂ emitted. By introducing carbon pricing, industries are incentivized to transform their activities to lower emissions⁹⁹. Many countries are introducing these tax measures to reduce emissions and meet their carbon neutrality targets. In 2021, the EY Green Tax Tracker¹¹¹ report provided a catalogue of sustainability tax measures related to carbon reduction across the globe. Despite the motivation to reduce carbon, many countries are still in the early stages of implementing carbon pricing. Based on current evidence and

¹¹⁰ CERCOM Deliverable D4.3 (2023), Case study III – NRAs Strategic Approach to Transitioning to CE ([Overview of Research Programmes Operations \(cedr.eu\)](#))

¹¹¹ [ey-green-tax-tracker-edition-1-final.pdf](#)



levels of implementation, the PIARC Special Report – Carbon Neutral Roads concluded that carbon pricing has limited impact on carbon emission reduction, although this is expected to increase in the coming years⁹⁹.

5.2.2.3. *Performance targets with incentives*

The ICE Guidance Note – Procurement and Contract Guidance on Delivering Net-Zero Carbon¹¹² discussed incentives within the procurement process and contract management to encourage carbon reduction, which would in turn foster circularity adoption. As well as introducing minimum requirements for achieving net-zero in the project scope, performance targets can also be set with incentives to encourage the supply chain to accomplish them. The requirements and targets need to be clearly defined in the tender assessment criteria to allow an objective and transparent assessment of compliance or non-compliance. Performance targets with incentives have a direct financial impact if targets are achieved or exceeded. Further guidance on the incorporation of performance targets within procurement contracts is provided in the published guidance note¹¹².

5.2.2.4. *Life cycle cost analysis*

Life cycle cost analysis (LCCA) is the process used to quantify the economic performance of processes, products or services over the entire service life (e.g., construction cost, operational cost, end of life cost, environmental costs). One benefit of LCCA is the inclusion of both direct and indirect costs associated with a proposal, both in the present and considering future economic trends (e.g., depreciation)¹¹³.

Currently, the cost effectiveness approach for evaluation of tenders within the GPP framework allows LCCA to be used as an indirect means to incentivize contractors to address CE by looking at optimization of whole life costs when submitting tenders¹¹⁰. The LCCA can have the effect of incentivizing improved environmental performance. For example, higher initial capital costs are often required to reduce environmental burden but using an LCCA approach, the benefits of potential lower life cycle running costs are also considered¹¹⁴. ISO 15686-5 provides guidance on carrying out LCCA for buildings and constructed assets.

5.3. Business case for implementation

Many business models associated with TI networks across Europe are largely based on a linear approach considering Cradle to Grave and focused on economic considerations as the main driver of decisions. Over the last few decades, changes have been made within business models and procurement procedures to increase the emphasis on sustainability,

¹¹² ICE Guidance Note – Procurement and Contract Guidance on Delivering Net-Zero Carbon ([How To Assess And Include Net Zero Carbon Targets In Procurement and Contracts | Institution of Civil Engineers \(ICE\)](#))

¹¹³ CERCOM Deliverable D4.1 & D4.2 (2023), Case studies I & II – Protocol and Results ([Overview of Research Programmes Operations \(cedr.eu\)](#))

¹¹⁴ Garbarino E., Rodríguez Quintero R., Donatello S., Gama Caldas M. and Wolf O.; 2016; Revision of Green Public Procurement Criteria for Road Design, Construction and Maintenance. Technical report and criteria proposal; EUR 28013 EN; doi:10.2791/683567



and more recently, to reduce carbon emissions. The following steps have been implemented to varying degrees to drive progress and change in this regard¹⁰⁵:

- Carbon emissions associated with maintenance activities.
- Updating standards to increase the use of recycled and secondary materials.
- Life cycle analysis and life cycle cost analysis to influence decision making.

Although steps have been taken to incentivize carbon emissions reduction and increase resource efficiency and circular economy, circular business models need to also be integrated to address the key circular principles to incorporate a cyclical Cradle to Cradle approach. The initial capital investment in circular approaches is generally higher than traditional approaches and updating business models to reflect added value of circular design, increasing resource efficiency, extending service life and residual value is essential¹⁰⁵.

CERCOM Deliverable D2.1¹⁰⁵ identified the following fundamental principles of CE that would be expected within a circular business model:

- Consideration of waste and pollution reduction at design stage.
- Approach that supports value retention of materials rather than waste management approach.
- Contracts that support extended contractor/supplier responsibility or infrastructure as a service.
- An emphasis on supply chain communication with early contractor involvement.
- Inclusion of functional based specifications, shifting the focus from outputs to outcomes.
- Approaches to incentivize innovation which would enable risk and benefit sharing between stakeholders.
- Reduce impacts of climate change and use of limited resources/virgin materials.

While most business models are still focused on a linear approach, there are some good examples of initiatives that are pushing boundaries and advancing towards a more circular business model approach. The Netherlands have introduced a pilot project which includes an 'infrastructure as a service' business model. The goal is to motivate investment in circular innovations over the lifetime of the contract, from design and operation to reuse. Over the specified contract length, the contractor remains the economic owner and operator of the asset¹¹⁰.

5.4. Summary of good practice

The following were identified as good practice approaches to foster circularity within TI:

- Communication between stakeholders and early engagement with the supply chain is vital.



- European and National regulatory frameworks and guidance documents impact the update of circular practices (e.g., procurement, waste management, carbon emissions, EPDs, organizational culture etc.)
- Tax incentives will likely have a role to play in reducing carbon emissions in the future.
- Updating of standards to allow for more innovative solutions and/or functional specifications with facilitate more circular approaches.
- Circular procurement taking account of life cycle costs rather than just initial construction costs will motivate circular thinking and foster change throughout the supply chain.
- ‘Infrastructure as a service’ contracts may be a suitable means to promote circular business models.
- Resource exchange mechanisms can contribute to resource efficiency and the protection of virgin materials.
- While innovative approaches to materials and methods are essential, engineers within TI must adequately manage and quantify associated technical performance risks together with circularity.
- Encourage data sharing and knowledge transfer between various stakeholders and TI sectors.
- Measure and collate data and report financial, societal and environmental benefits of circular approaches.
- Further work is required to develop KPIs specifically addressing CE. For the current level of maturity of most TI administrations it is more efficient to identify KPIs related to critical aspects or specific parts of the overall process.



6. DMIGF Proposal and Discussion

6.1. Introduction

LIAISON aims to provide knowledge and technical solutions to reduce emissions arising from transport infrastructure (TI). The project will investigate smart and sustainable beams, rigid road pavements and improved ballast; bioasphalts and smart pavement inspection systems; intelligent tunnel control systems and photovoltaic guardrails. LIAISON covers the whole life cycle of TI, providing a means to limit the overall emissions from construction, maintenance, operation and decommissioning of the infrastructure.

The LIAISON **Dynamic Multi-Infrastructure Governance Framework (DMIGF)** is a methodology to facilitate the transformation of EU Transport Infrastructure into a more circular and low carbon economic activity. Within LIAISON, the methodology will be validated with five demonstration pilots. Following completion of the project, the DMIGF will provide organisations with a quantitative risk-based assessment methodology to evaluate the circular economy potential of TI carbon-neutral construction, operation and maintenance, and decommissioning strategies. With its circular approach, the new governance framework will have the capability to foster scalability and replication of LIAISON's innovative solutions.

6.2. Alignment with Level(s) approach

As well as incorporating a risk-based assessment methodology, the goal of the DMIGF is to broadly align with the Level(s) methodology (discussed in Section 4.3, Table 6). This will be achieved by providing support indicators and digital tools to monitor the environmental impact of the design, construction, operation, maintenance and decommissioning of Transport Infrastructure.

Alignment with Level(s) will be achieved by providing support indicators and digital tools to monitor the environmental impact of the design, construction, operation, maintenance and decommissioning of Transport Infrastructure. Five DMIGF categories are currently identified to encompass all indicators relevant to TI. Five DMIGF categories are currently identified to encompass all indicators relevant to TI. Figure 6 illustrates the relationship between the Level(s) macro-objectives and the five categories that are proposed within the DMIGF. Within each category, a range of indicators applicable to TI will be identified or developed to adequately assess the impact of each of the Demo Cases. The indicators can be applied at various stages of the process; at conceptual design, detailed design and construction, or during the operation and maintenance phase.



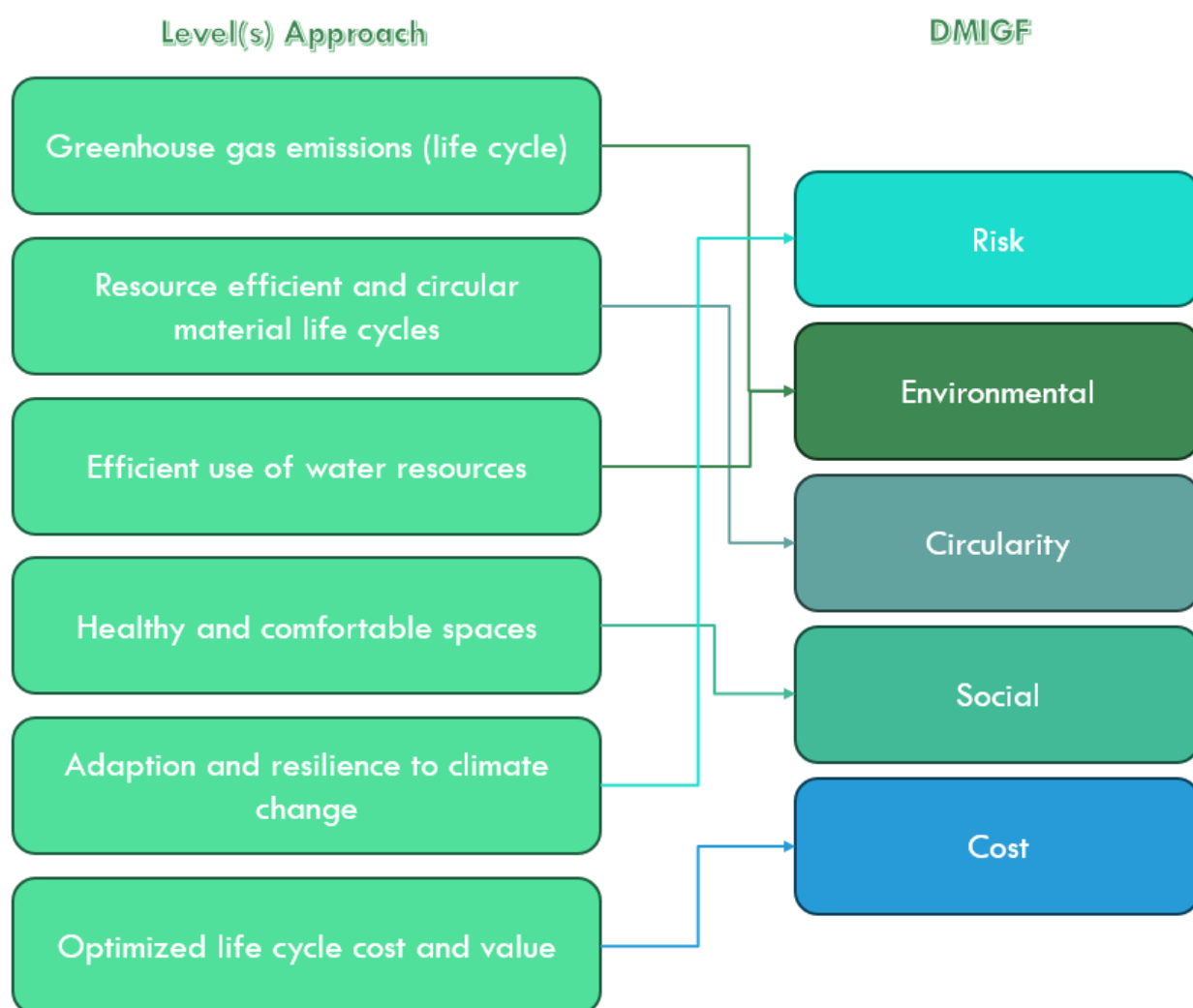


Figure 6 Relationship between Level(s) macro-objectives and DMIGF categories

Level(s) has a defined set of 16 indicators to be applied at various phases. Given the wide variation of technologies and applications within TI, it is envisaged that there will be a database of KPIs defined within each category. For each Demo Case, specific indicators will be selected to accurately reflect the impact of the approach within each category. The goal is to also assess at least one additional established approach in parallel, to provide a benchmark or reference case.

In line with the Level(s) approach, the Demo Cases have been selected to provide validation of the DMIGF at each stage of a project, from conceptual design through to operation and end of life (Figure 7).



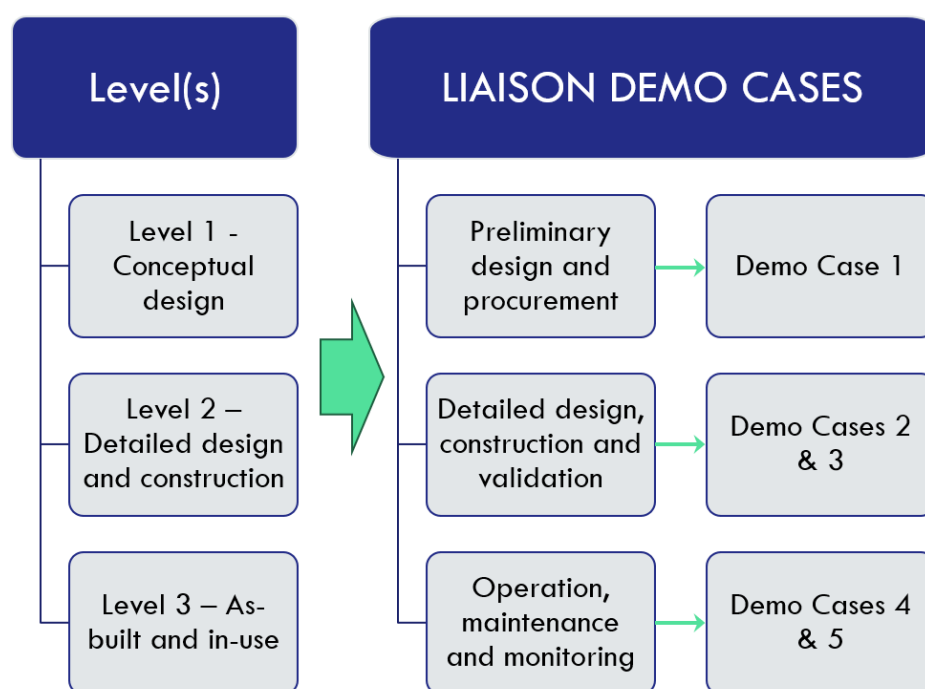


Figure 7 Relationship between Level(s) approach and LIAISON Demo Cases

6.3. Risk-based methodology

Risk management processes form an integral part of the management of transport within strategic planning and change management. Within LIAISON, a risk-based methodology is established to assess and compare the technical risks associated with innovative approaches and more traditional methods. The risk-based approach will follow established risk-based methodologies, such as those outlined in ISO 31000:2018 Risk management — Guidelines¹¹⁵.

A preliminary assessment methodology is outlined in Figure 8. This is similar to the established tried and tested CERCOM¹¹⁶ approach which has been adapted to meet the specific requirements of LIAISON. There are 6 steps involved in the process:

- **Establish context** - Includes the primary goals of the assessment, identification of the spatial and temporal boundaries of the assessment in question and the scope of the analysis.
- **Evaluate likelihoods** - Includes analysis of the technical engineering performance and identification of the likelihood of inadequate performance or the probability of exceedance of a given damage state within the specified reference period.
- **Evaluate consequences** - Includes direct and/or indirect consequences/costs associated with inadequate performance.

¹¹⁵ International Standards Organisation (2018), "ISO 31000:2018 Risk Management Guidelines"

¹¹⁶ CERCOM Deliverable D3.1 (2022), Guideline Detailing Roadmap to Implementation ([CERCOM-D3.1-Guideline-Detailing-Roadmap-to-Implementation.pdf](https://cedr.eu/CERCOM-D3.1-Guideline-Detailing-Roadmap-to-Implementation.pdf) (cedr.eu))



- **Quantify Additional Indicators** - Involves identification and quantification of additional indicators within the categories; Circularity, Cost, Environment and Social.
- **Evaluate Uncertainties** – Includes analysis to identify the level of confidence or uncertainty associated with the quantification of the indicators.
- **Reporting and Monitoring** – Ongoing monitoring and data analysis of input data, updating of analysis and reporting and communication.

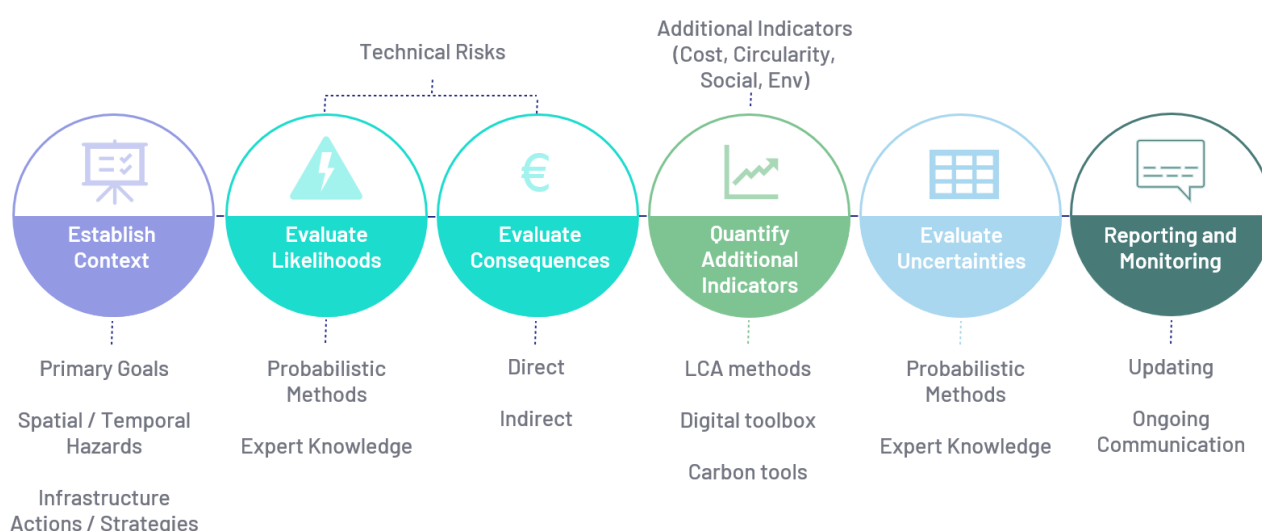


Figure 8 Proposed DMIGF risk-based methodology

For each potential construction or maintenance option being considered, the risks associated with this strategy will be calculated ($Risk = Likelihood\ of\ inadequate\ performance \times Consequences\ of\ inadequate\ performance$). Performance indicators for risk will be defined specifically for each Demo case. To quantify these indicators, the likelihood of each product/method not reaching or maintaining a specified performance level will be evaluated (defined specifically on a case-by-case basis). The consequences associated with this insufficient performance level will also be calculated to provide a full indication of risk.

The risk analysis may be completed using probabilistic methods (e.g., Monte Carlo Simulation, Bayesian Networks and Fault Trees) if sufficient data is available. For example, to calculate the likelihood of inadequate performance (or insufficient technical performance), the indicator relating to performance can be modelled stochastically and used to compare the novel or innovative approach to a more traditional method using a defined performance threshold. In this case, the mean level of performance can be evaluated as well as the spread in the performance data, providing a more accurate reflection of the performance. The spread of data or range of results associated with one approach may be larger, resulting in a higher proportion of the curve below the threshold level even where the mean values are the same, as indicated in Figure 9.



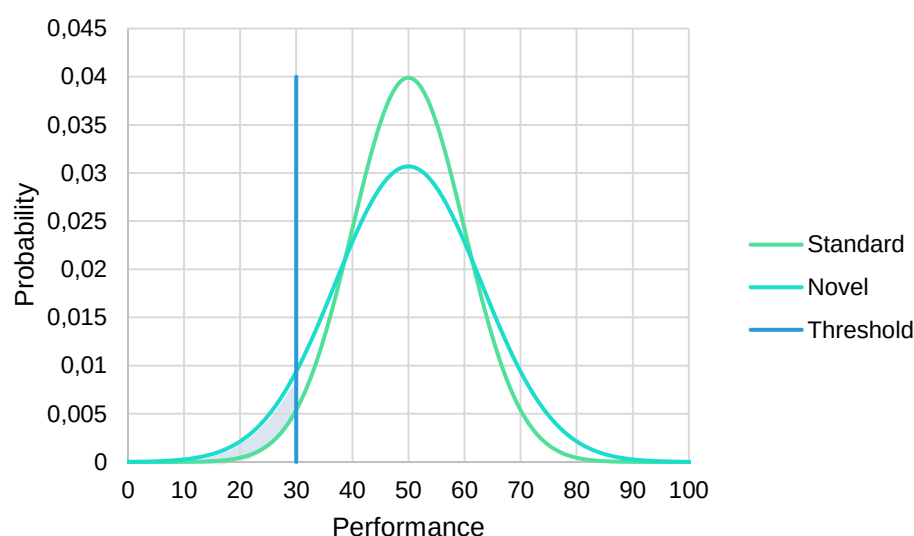


Figure 9 Stochastic modelling of performance to calculate likelihood of inadequate performance

Where there is insufficient data for probabilistic modelling, a more qualitative approach can be taken to evaluate the likelihood of inadequate performance. An example is provided in Figure 10, where the expected average performance and spread of data (deviation of results), result in a High, Medium or Low likelihood of inadequate performance. Each of these categories are associated with a likelihood of inadequate performance value between 0 and 1. This can be customised to suit the range of data or level of expertise, with more or less ranks assigned to the matrix. The consequences associated with inadequate performance must also be evaluated and quantified in terms of monetary value. The product of the consequences and likelihood of inadequate performance provide a quantitative assessment of risk.

		Average Performance		
		Below Average	Average	Above Average
Spread of Data	Above average	High	Medium	Medium
	Average	Medium	Medium	Low
	Below average	Medium	Low	Low

Figure 10 Qualitative matrix-based approach to evaluate likelihood of inadequate performance

Alternatively, where a more simplistic risk assessment is sufficient, a similar matrix-based approach can be used to qualitatively evaluate risk (rather than the individual likelihood and consequence evaluation). A sample matrix is provided in Figure 11. The likelihood and consequence severity can be selected based on limited data or expert judgement to determine risk. Each category within the matrix is assigned a value and can then be used to compare various scheme or project options.



		Consequence Severity			
		1	2	3	4
Likelihood of inadequate performance	1	Low	Low	Medium	Medium
	2	Low	Medium	Medium	High
	3	Medium	Medium	High	High
	4	Medium	High	High	High

Figure 11 Qualitative matrix-based approach to evaluate risk

6.4. Additional indicators

Given the level of data and expertise currently related to circularity, it is more efficient to identify KPIs related to critical aspects or specific parts of the overall process. On this basis, the use of indicators relating to specific factors and quantities will be adopted within the initial development of the DMIGF, with the option to include single or multiple indicators within each category. A sample list of potential indicators within each category was compiled and discussed with Demo Case leaders during WP1 DMIGF development workshops. Following the workshops, specific indicators relevant to each project will be identified. A sample of potential indicators under each category is presented in Figure 12. The indicators within each category can then be aggregated or combined in the final step of the DMIGF (discussed further in Section 6.7).

The potential to propose a more complex combined indicator for circularity as part of LIAISON will be discussed and investigated as the development of the DMIGF and Demo Cases progresses.

LCA will be used to quantify indicators in the project. An initial overview of the process is provided in the following subsection.



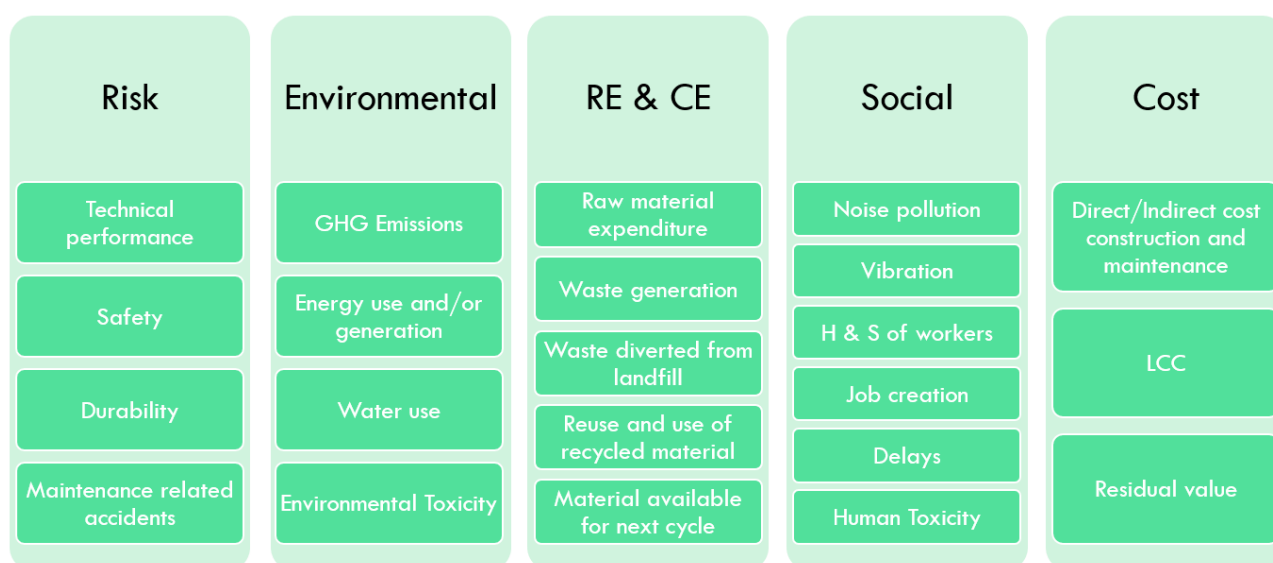


Figure 12 Sample indicators under each category

6.4.1. Life Cycle Assessment (LCA)

The execution of Life Cycle Assessment (LCA) within the DMIGF serves as a pivotal means to quantitatively analyse various indicators, primarily those pertaining to environmental considerations. Nonetheless, there exists a potential overlap with other categories such as Social and Cost (LCS and LCC), contingent upon the specific Demo Case and Indicators under examination. The LCA methodology adheres to the ISO14040 standard, furnishing a comprehensive framework, terminologies, and methodological phases, which are implemented across four stages^{117,118,119}:

- **Goal and Scope Definition:** This stage articulates the analysis's purpose, objectives, system parameters, boundaries, and functional unit.
- **Life Cycle Inventory:** Herein lies the collection of requisite data to analyse the Life Cycle Inventory (LCI).
- **Assessment of the environmental impact:** Utilizing the Life Cycle Impact Assessment (LCIA) methodology, this phase encompasses the classification, characterization, and normalization of LCI flows to estimate potential environmental impacts.
- **Interpretation:** This final stage entails the identification, quantification, and evaluation of information derived from the preceding stages. Effective communication of findings and recommendations for system enhancements are paramount.

¹¹⁷ Teixeira, E. R., Mateus, R., Camoes, A. F., Bragança, L., & Branco, F. G. (2016). Comparative environmental life-cycle analysis of concretes using biomass and coal fly ashes as partial cement replacement material. *Journal of Cleaner Production*, 112, 2221-2230.

¹¹⁸ Celik, K., Meral, C., Petek Gursel, A., Mehta, P.K., Horvath, A., Monteiro, P.J.M., 2015. Mechanical properties, durability, and life-cycle assessment of self-consolidating concrete mixtures made with blended Portland cements containing fly ash and limestone powder. *Cem. Concr. Compos.* 56, 59e72. <http://dx.doi.org/10.1016/j.cemconcomp.2014.11.003>.

¹¹⁹ Junior, A. C. P., Jacinto, C., Turco, C., Fernandes, J., Teixeira, E., & Mateus, R. (2022). Analysis of the effect of incorporating construction and demolition waste on the environmental and mechanical performance of earth-based mixtures. *Construction and Building Materials*, 330, 127244.



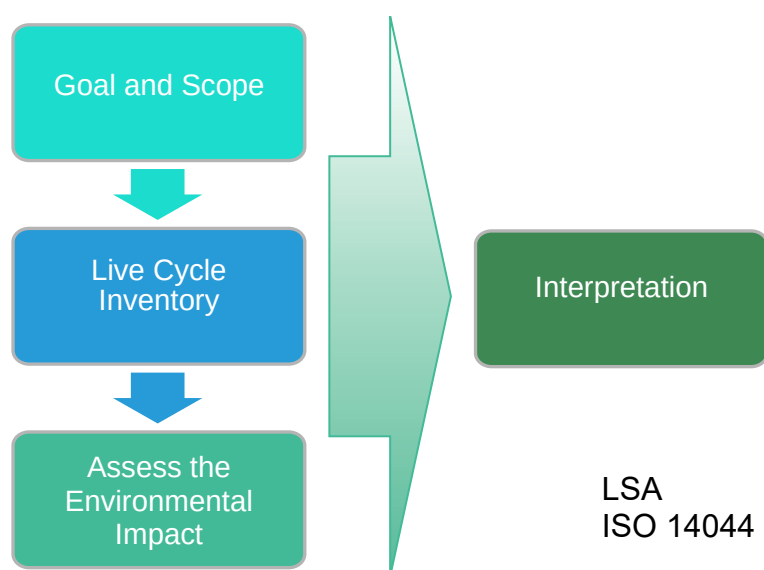


Figure 13 Life Cycle Assessment Methodology

6.4.1.1. *Goal and scope*

The main goal of the LCA is to evaluate the environmental impacts of each Demo Case, validating the quantification methodology integrated into the DMIGF and facilitating the framework's upscaling. The adopted LCA methodology incorporates a comparative analysis and aggregation of indicators, leveraging the Multi-Criteria Decision Support Methodology for Relative Sustainability Assessment of Building Technologies (MARS-SC)¹²⁰. This methodology encompasses environmental, functional, and economic sustainability categories¹²¹, with potential inclusion of social components. Within the DMIGF, MARS-SC will be utilized specifically for environmental impacts, up to the normalization phase.

Functional unit and system boundaries:

Traditionally, the life cycle stages of transportation infrastructure comprise four main phases (Figure 14). However, with the advent of the Circular Economy, certain components may undergo a "cradle-to-cradle" analysis, wherein end-of-life materials return to initial stages. Depending on the Demo Cases, various infrastructure lifecycle assessments are feasible:

- **Cradle-to-gate:** Assessing the footprint until infrastructure completion, excluding use and end-of-life considerations.
- **Cradle-to-grave:** Encompassing all phases from design to end-of-life.
- **Cradle-to-cradle:** Similar to cradle-to-grave but incorporating recycling/upcycling to extend material lifespan.

For each Demo Case, defining the functional unit and boundaries ensures a representative LCA assessment.

¹²⁰ J. Fernandes, R. Mateus, L. Bragança, The potential of vernacular materials to the sustainable building design, in: M. Correia, G. Carlos, S. Rocha (Eds.), Vernac. Herit. Earthen Archit, 1st ed., CRC Press, Leiden, 2013, pp. 623–629, <https://doi.org/10.1201/b15685-108>

¹²¹ R. Mateus, S. Neiva, L. Bragança, P. Mendonça, M. Macieira, Sustainability assessment of an innovative lightweight building technology for partition walls - comparison with conventional technologies, Build. Environ. 67 (2013) 147–159, <https://doi.org/10.1016/j.buildenv.2013.05.012>.



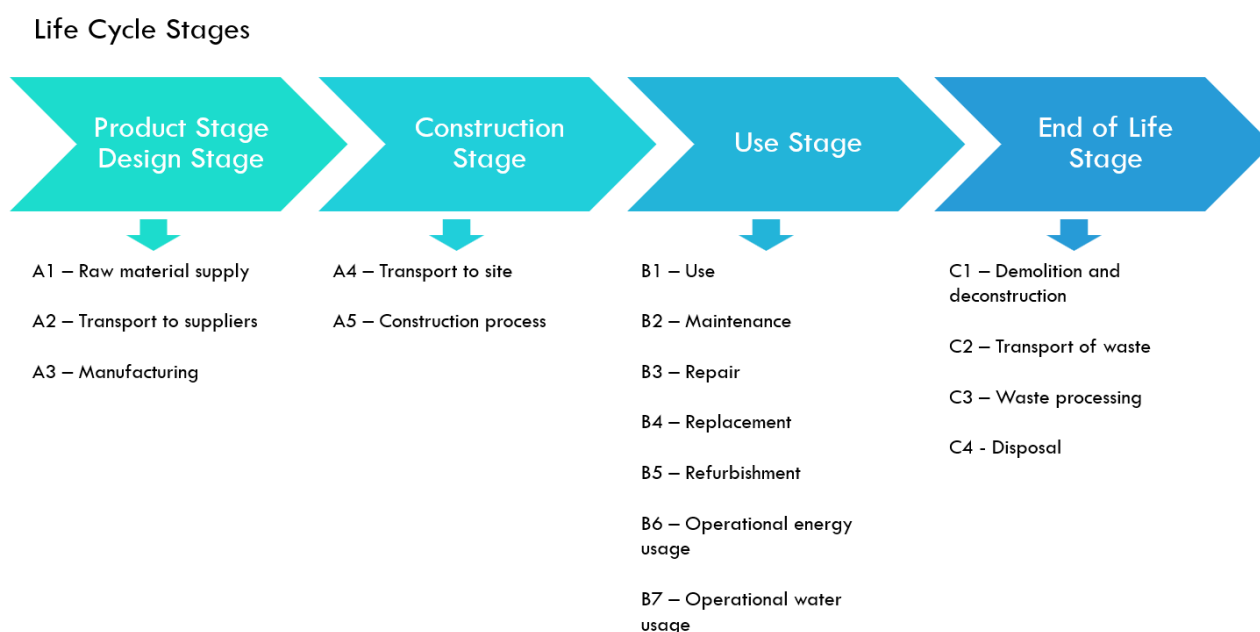


Figure 14 Transportation Infrastructure Life Cycle Phases

6.4.1.2. Life Cycle Inventory (LCI)

The Life Cycle Inventory quantifies inputs (e.g., energy, raw materials) and outputs (e.g., emissions, wastes) within specified boundaries for each Demo Case, culminating in database creation. This inventory is context-specific and relies on available Demo Case data, supplemented by external sources like Ecoinvent when necessary. Analysis of the life cycle inventory employs software such as SimaPro, facilitating impact category quantification.

6.4.1.3. Life Cycle Impact Assessment (LCIA)

LCI data undergoes conversion into potential environmental impacts using various LCIA methods:

- CML-IA baseline method is used to assess the environmental indicators expressed in impact categories, such as: global warming, ozone depletion, soil and water acidification, eutrophication, photochemical ozone creation;
- GHG – is used for carbon assessment (CO₂ eq);
- Cumulative Energy Demand (CED) method to the life cycle energy used to assess the depletion of abiotic resources of fossils fuels

To address scale effects in aggregating various environmental impacts and ensure consistency across parameters, normalization is employed utilizing the Diaz-Balteiro equation¹²²:

$$\bar{P}_i = \frac{P_i - P_{*i}}{P_i^* - P_{*i}} \quad \forall i \quad (1)$$

¹²² L. Díaz-Balteiro, C. Romero, In search of a natural systems sustainability index, Ecol. Econ. 49 (2004) 401–405, <https://doi.org/10.1016/j.ecolecon.2004.02.005>.



Here P_i represents the value of i^{th} parameter; while P_i^* and P_{*i} denote the best and worst values, respectively, of the i^{th} sustainability parameter. Normalization transforms values into a scale bounded between 0 (worst value) and 1 (best value), rendering each environmental indicator dimensionless.

6.5. Uncertainty

As well as evaluating the risk associated with technical performance of various approaches within each Demo case, it is proposed to evaluate the uncertainty associated with the quantification of the additional indicators. The objective is to perform analysis to provide a deterministic value with an associated uncertainty level or confidence/error bar. Similar to risk analysis, there are various approaches that can be taken depending on the level of data and/or experience associated with the product or method. Figure 15 illustrates how the spread of data can indicate the level of uncertainty associated with a deterministic value assigned to an indicator.

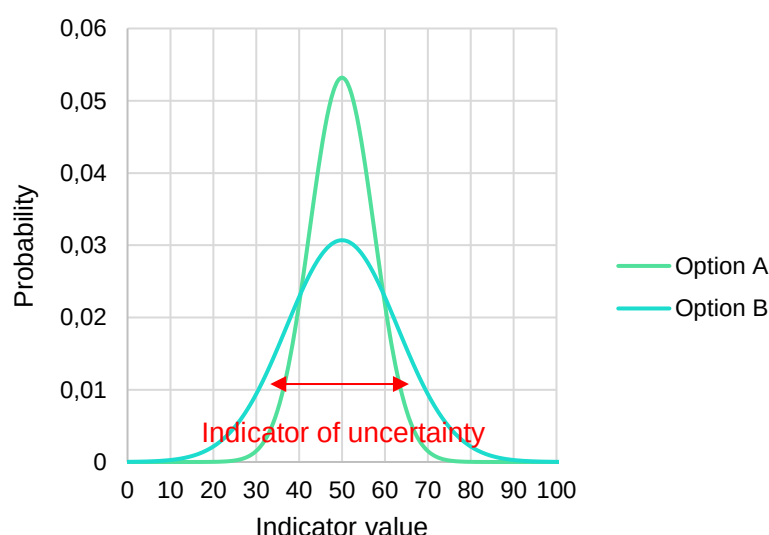


Figure 15 Stochastic modelling to evaluate uncertainty

Similar to the risk analysis, a more qualitative approach can also be taken to evaluate uncertainty associated with deterministic values of indicators. The approach taken in hueCO₂¹²³ is qualitative and considers various different factors when determining the level of uncertainty. The process is outlined in Figure 16. There are 4 criteria headings (*Source, Geographical Relevance, Age of Data and Calculation Methodology*). The user assigns a score for each criteria heading, between 1-3, based on the descriptions in the table. The average of the 4 values is then taken as the average uncertainty score, and a percentage uncertainty is assigned based on this value.

¹²³ Tecniberia, hueCO₂ User Guide, <https://hueco2.tecniberia.es/>



Score	Criteria				Average Score	% Uncertainty
	Source	Geographical relevance	Age of data	Calculation methodology		
1	Reliable source	Local	< 2 years	Recognised/accredited methodology	1 - 1.5	5
	Regognised		2 - 5 years	Own methodology	1.5 - 2	10
2	source	National	years	independently verified	2 - 3	20
3	Not regnngised	International	> 5 years	Own methodology not verified		

Figure 16 Qualitative approach to evaluate uncertainty based on 4 criteria headings

This can again be simplified using a matrix-based approach, by reducing the criteria considered to two categories, with various possible entries. An example is provided in Figure 17. In this case, the criteria considered are *Calculation Methodology* and *Source*. The user can select from 3 possible entries for each criteria, resulting in a colour coded uncertainty level and associated percentage uncertainty. The procedure or approach taken to determine the uncertainty level can be evaluated on a case-by-case basis.

		Calculation methodology		
		Reliable source	Recognised source	Not recognised
Source	Recognised/accredited methodology			
	Own methodology independently verified			
	Own methodology not verified			

	% Uncertainty
	5
	10
	15
	20

Figure 17 Qualitative matrix-based approach to evaluate uncertainty

6.6. Normalization of indicators

A number of methodologies were investigated to normalize indicators within each category, including:

- ranking system with interpolated values
- direct formula, indicators normalized using reference values (e.g., budget)
- consideration of the Diaz-Balteiro equation (section 6.4.1.3)

When developing the methodology, a number of essential aspects relating to the KPIs must be considered before the aggregation step:

1. Indicators should be quantified between 0.0 and 1.0.
2. Indicators should be normalized against some constant / maximum value.
3. Indicators should be as orthogonal (statistically independent) as possible.



4. Indicators should be quantified using transparent and repeatable methods.

The procedure for normalizing indicators by ranked interpolation is as follows (Figure 18):

1. Determine the number of ranks required to quantify indicator.
2. Set the minimum rank to a value of 0.0, and the maximum rank to a value of 1.0.
3. Determine the mathematical relationship between each rank (linear/non-linear).
4. Score the indicator for the scenario being evaluated and interpolate according to ranked relationship.

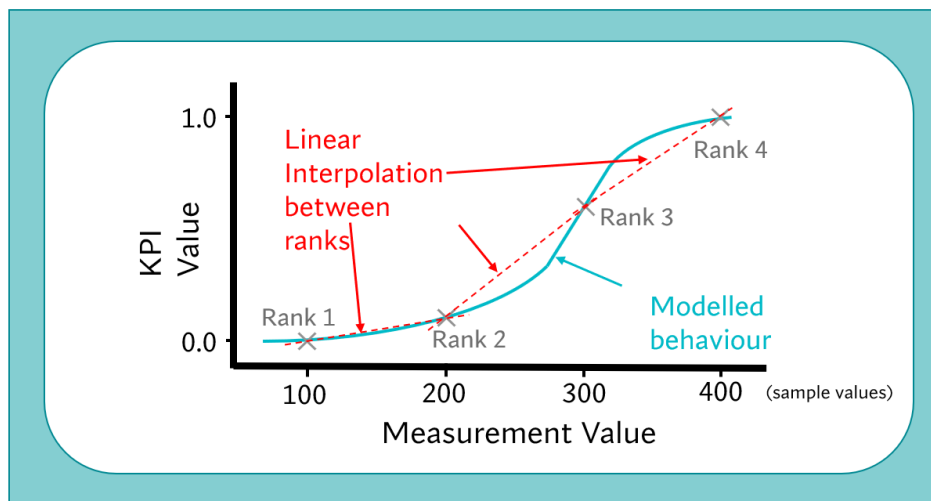


Figure 18 Ranked interpolation approach

The ranked interpolation procedure using 2 ranks (i.e., linear interpolation) is similar to the approach outlined for LCA in Section 6.4.1.3.

An alternative approach is to translate all indicators to a monetary value using methods and benchmarks provided in established databases. To normalize between 0 and 1, one option is to use the capital budget for the project as a standard reference for all indicators. A sample equation using CO₂ as an environmental indicator is provided in Equation (2). The quantity of CO₂ emissions associated with the project is quantified in tonnes and converted to an equivalent monetary value in Euros. The normalized indicator is calculated by dividing this value by the direct capital cost of the project in Euros.

$$ICO2_{Project} = \frac{€tCO2_{Project}}{€CD_{Project}} \quad (2)$$

where:

$ICO2_{Project}$ = Value of normalized CO₂ indicator

$€tCO2_{Project}$ = quantity of CO₂ emissions converted to Euro equivalent

$€CD_{Project}$ = Direct capital cost of project in Euro

While ranked interpolation provides a means to represent multi linear behaviour, using the approach of normalizing using a standard monetary value could provide a consistent,



transparent and robust method for normalizing indicators and for inclusion in the DMIGF for procurement procedures. Online resources and databases for calculating carbon emissions, such as hueCO₂¹²⁴ or the TII Carbon Tool¹²⁵, may be used to provide reference data to convert and normalise indicators.

The method used will be decided on a case-by-case basis following analysis of the quantity and type of data available for each Demo case. It should be noted that the Diaz-Balteiro equation may be employed within the LCA process or as part of indicator normalisation across categories.

6.7. DMIGF process

Following the development of categories aligning with the Level(s) approach and an outline of the risk-based analysis, further development of the DMIGF involves the identification of the methodology and procedures at various stages throughout the process.

The potential to finalise the process by consolidating all indicators into a single resultant metric was considered and discussed, but it was concluded that this would result in a loss of accuracy and potential dilution of results from various categories, depending on the weighting applied between each category.

On this basis, it is proposed that the DMIGF provides the capacity to aggregate indicators within each category, providing a combined category indicator. The process involved in the various stages of the framework is presented in Figure 19. The first step is identifying the two (or more) approaches to be considered and compared. For each Demo Case, the innovative approach proposed and developed within LIAISON will be compared to a more traditional standard approach to provide an indication of the relative benefits of the developed technology within each category. The 5 categories outlined in Section 6.2 form a critical element of the DMIGF and the goal is to identify and define single or multiple relevant indicators within each category that will be analysed for both the Standard Approach (SA) and Innovative Approach (IA).

Quantification of each indicator will then be completed using a combination of various forms of data available (e.g. site data, laboratory data, published reference data, historic data, etc.). As discussed above, uncertainties associated with the quantification of the indicators will also be addressed, taking account of the quantity and quality of data available.

¹²⁴ [HueCO₂ | Carbon footprint of public works construction \(tecniberia.es\)](https://www.tecniberia.es/hueco2/)

¹²⁵ [GE-ENV-01106 \(tiipublications.ie\)](https://www.tiipublications.ie/ge-env-01106)



D1.1: LIAISON DMIGF Methodology – Initial version

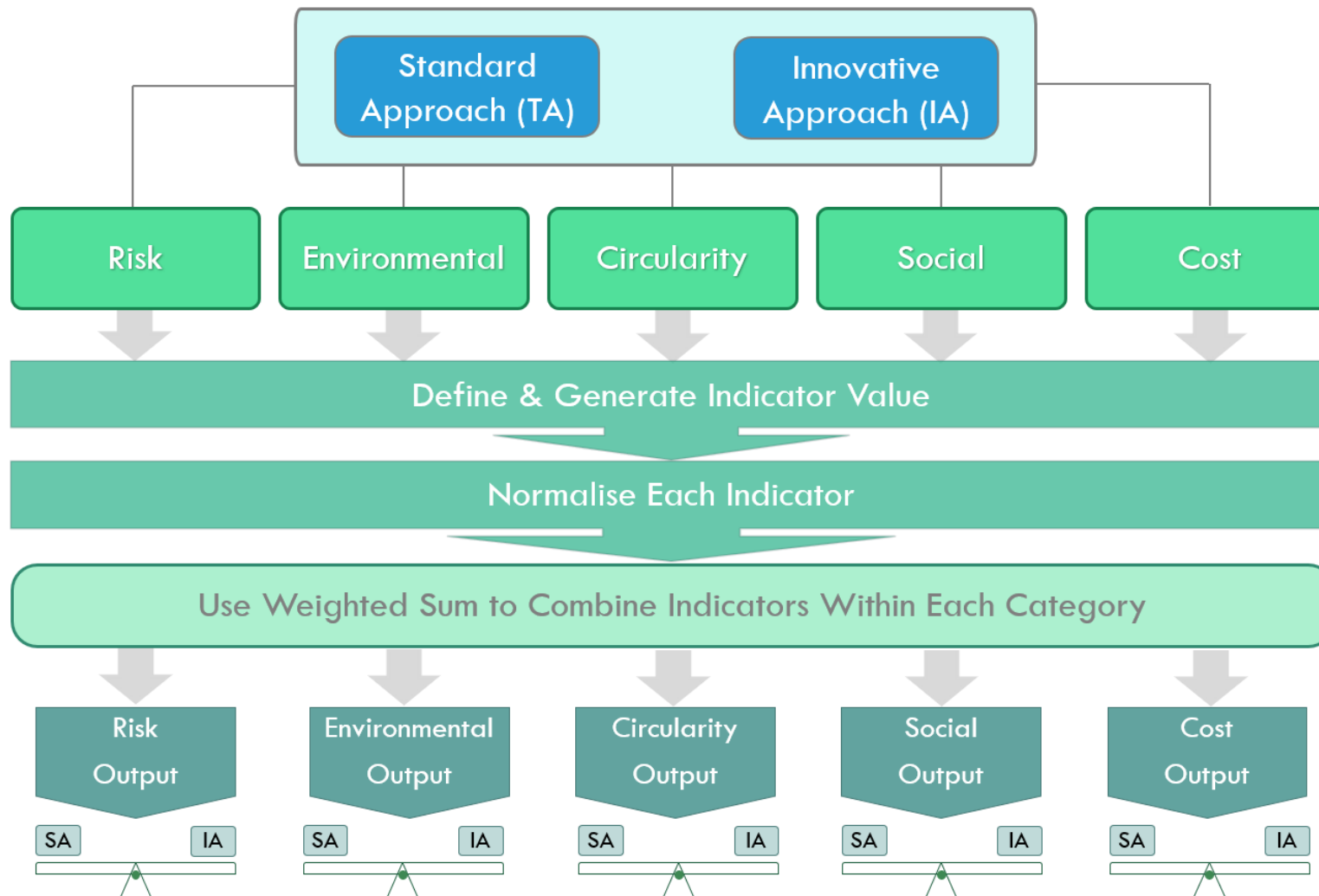


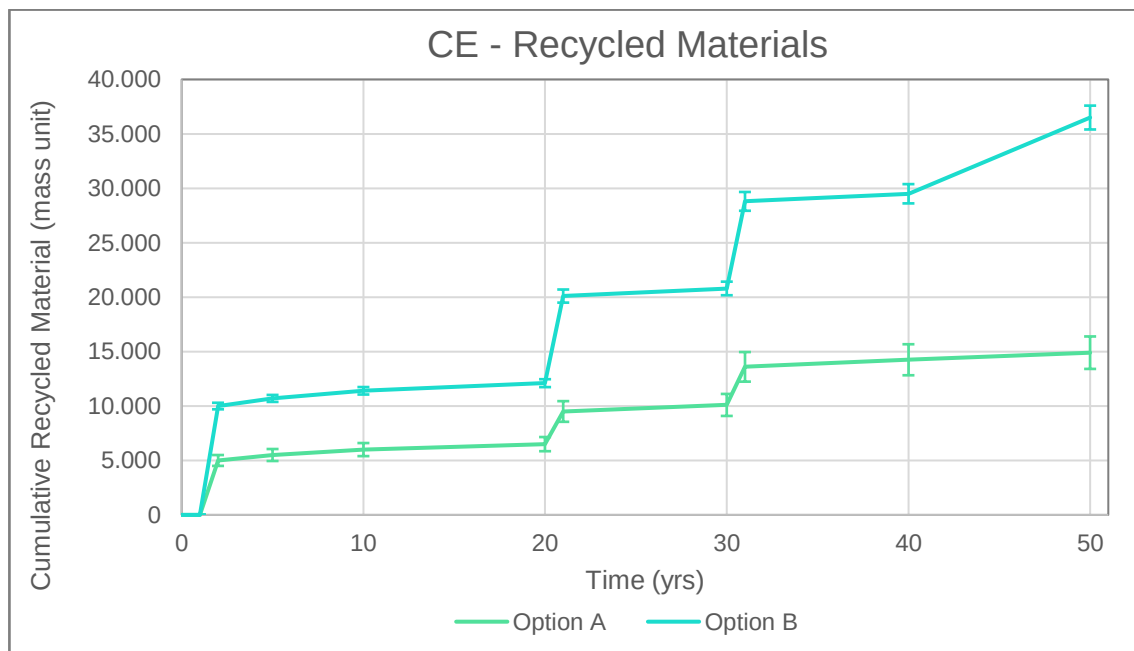
Figure 19 DMIGF for aggregated KPI metric for each category



When generating, quantifying and presenting results related to individual indicators as part of the DMIGF, two approaches were considered and are presented in Figure 20, taking mass of recycled materials as an example indicator within the circularity category. Figure 20(a) illustrates a time dependent approach, where the evolution and cumulative measure of the indicator over the reference period is determined and presented in graphical format to be used as a decision support tool. An alternative approach is to present the final cumulative sum at the end of the reference period (Figure 20(b)). With both approaches, there is the capability to include the level of confidence in the data using error bars.

Both approaches provide the same final result, a quantification of the cumulative sum over the reference period. The time-dependent graphical representation provides more detailed information to the user of the breakdown over the reference period. However, the single value result (Figure 20(b)) was deemed to be more suitable for the DMIGF, particularly for Demo Case 1, since it provides a more straightforward way of integrating results of the DMIGF into procurement procedures where metrics need to be very clear and objective.

The reference period may be defined as the service life of a product, the period between significant maintenance and/or repair, or any period which considers a combination of these factors as well as political / governance of the overseeing organisation. Ideally, the reference period should consider a multi-lifecycle approach, taking account of factors such as end-of-life, recyclability and/or residual value at the end of the reference period. This is central to the concept of circularity for the LIAISON project.



(a)



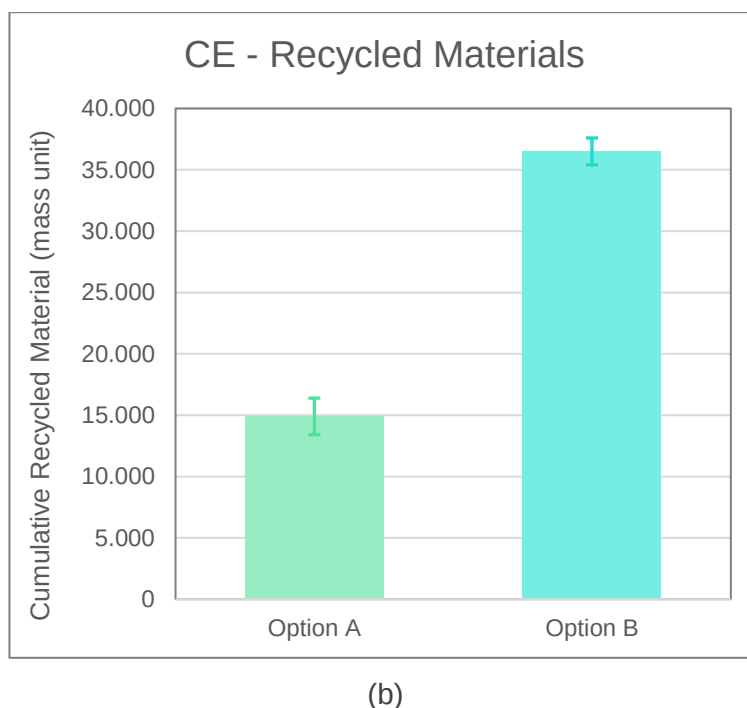


Figure 20 Incorporation of LCA into DMIGF (a) time dependent approach (b) cumulative value over reference period

It is envisaged that the LCA and Digital Toolbox will be among the tools and methods used to quantify each of the indicators and associated uncertainties. In order to aggregate indicators within each category, it will be necessary to normalize indicators between a value of 0 and 1 to provide a robust and transparent method of combining indicators (discussed in more detail in Section 6.6). The ability to assign weights to each of the indicators as part of this procedure will be investigated throughout implementation of the DMIGF to ensure all indicators are adequately represented. The results for each category will then be presented, providing a means to assess and compare various innovative and standard approaches within each of the categories (i.e., Risk, Environmental, Circularity, Social and Cost).

The framework has been developed in such a way that it can be implemented differently for each Demo case, taking account of the project phase, availability of data and range of potential indicators.

6.8. Indicative examples (with virtual data)

6.8.1. Risk / Technical performance

A simple example is provided to demonstrate the process of determining risk related to technical performance. This is followed by a simple example of how average carbon emissions associated with a particular material used in the construction of a road pavement can be used to generate an indicator for carbon emissions within the Environmental category. It is noted that these examples are based on dummy data and should be used only as a means to understand a simplified process for



assessing risk. Further examples will follow through the course of the LIAISON project, with the examination of various demonstration cases. In these cases, a full analysis will be completed, considering a more thorough risk assessment, including analysis of boundary conditions and a range of indicators.

For this example, pavement resurfacing is taken as an example. The stiffness of the binder course is assumed to be an indication of the durability of the pavement. As such, material stiffness for the asphalt is chosen as an indicator of durability. To provide a means to quantify adequate performance, reference is made to current standards relating to road design¹²⁶ and a threshold value of 3100 MPa is used for this indicative example to represent minimum adequate performance in terms of asphalt material properties. This indicator can be used to assess various different scheme options or approaches, to compare standard and innovative methods. A single example (e.g. for a standard asphalt) is outlined here to demonstrate the process.

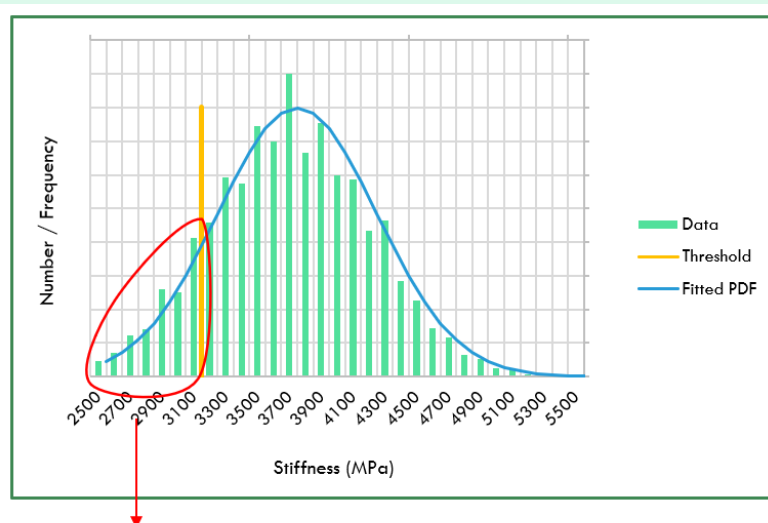
Data to quantify material stiffness can be based on:

- experimental / laboratory data
- site data
- reference data

Once data is collected, a histogram can be generated and a probability distribution function (PDF) can be fitted to the data to determine the likelihood of inadequate performance. Figure 21 illustrates the histogram of test results for this example and the outline of the fitted PDF (normal distribution in this example). The area under the PDF is equal to 1. The threshold value indicating sufficient performance is also highlighted, and the likelihood of inadequate performance is estimated by taking the area under the curve that is less than the threshold value. In this case, this equates to a value of 0.12.

¹²⁶ National Highways, Design Manual for Roads and Bridges, CD226 Design for new pavement construction, November 2021, (Appendix A)





Area under curve below threshold used to
quantify likelihood of inadequate
performance = 0.12

Figure 21 Quantitative approach to determine likelihood of inadequate performance

The next step is to evaluate the consequences of inadequate performance in terms of monetary value. A value of €100,000 is taken for this example. This results in a risk also expressed as a monetary value ($\text{Risk} = 0.12 \times \text{€}100,000 = \text{€}11,507$). The risk can be normalised using the methods discussed in Section 6.6. In this example, a value representing the direct cost of the project is used to normalise the risk to a value between 0 and 1 ($\text{Normalised risk} = \text{€}11,507 / \text{€}250,000 = 0.046$). Given this example relates to a standard approach, the assigned level of uncertainty is Low, corresponding to an uncertainty of 5%. The results for this example are outlined in Figure 22.

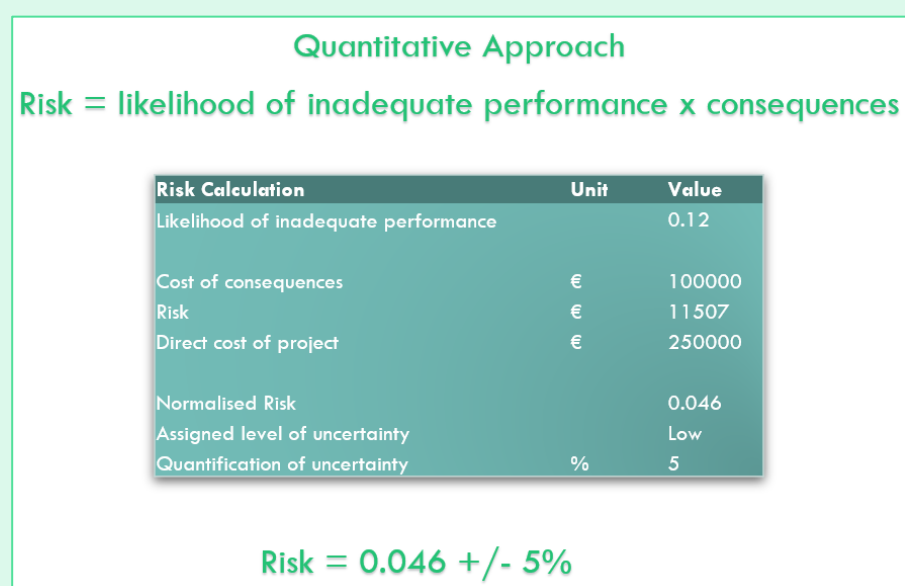


Figure 22 Indicative example – calculation of risk and associated uncertainty.

If data is not available to generate a histogram, expert experience or judgement can be used to perform a qualitative assessment. Using a matrix-based approach, the likelihood of inadequate performance and associated consequences are assigned a value between 1 and 4. A value of 1 indicates the lowest likelihood of inadequate performance and a value of 4 indicates the highest likelihood of inadequate performance. A value of 1 indicates a low consequence impact, and a value of 4 is associated with the highest consequence severity. For this example, the likelihood value is taken as 1 and consequence severity is taken as 2. Referencing the risk matrix, this results in a low risk. Values of risk corresponding to matrix entries will be discussed and finalised as the project progresses. For demonstration purposes for this example, an indicative value of 0.05 is taken for the “low risk” category. Given the qualitative nature of the assessment, the level of uncertainty is assumed to be Medium-High, resulting in an uncertainty level of 15%. Figure 23 illustrates the results of the qualitative analysis.

		Consequence Severity			
		1	2	3	4
Likelihood of inadequate performance	1	Low	Low	Medium	Medium
	2	Low	Medium	Medium	High
	3	Medium	Medium	High	High
	4	Medium	High	High	High

Likelihood of inadequate performance	1
Consequence severity	2
Corresponding risk	Low (0.05)
Level of uncertainty	Medium-high
Quantify uncertainty	15%

Risk = 0.05 +/- 15%

Figure 23 Indicative example – qualitative approach to determine risk and uncertainty

The qualitative approach and quantitative approach in this example resulted in similar mean values for risk (0.046 and 0.05). To demonstrate the impact and importance of assessing uncertainty, a comparison is made between both results in Figure 24. It is noted that this example is based on dummy data, and is not representative of a real example, but does indicate how the quality of data can influence the final result. There is a higher level of uncertainty associated with the qualitative approach, and this must be taken into consideration when interpreting the final results of analysis and evaluating various scheme or project options.

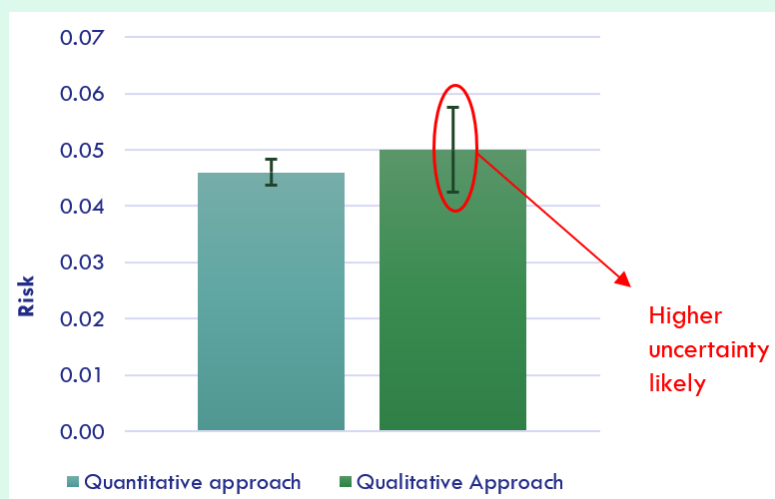


Figure 24 Comparison of potential quantitative and qualitative approaches

6.8.2. Environmental category – Carbon emissions

For the Environmental, Circularity, Social or Cost categories, indicators can be based on a full LCA, considering various aspects throughout the life cycle. In some cases, the data or expertise may not be available for this level of analysis. Or in other cases, the approach, transportation, construction methods, maintenance schedule and other aspects throughout the life cycle may be similar for standard and innovative approaches, and the main difference may be related to the use of alternative and/or more sustainable materials. Depending on the scope and objectives of the study, it may be sufficient to define an indicator based on individual material properties or factors.

Here we take average carbon emissions as an example within the Environmental category. For a road pavement resurfacing scheme, there may be various options considered, including hot rolled asphalt or a more innovative solution such as bioasphalt. As an example, the emission factor associated with 80mm deep dense asphalt is approximately 13.65 Kg CO₂/m² ¹²⁷. This reflects the embodied emissions (GHG emissions associated with material extraction and manufacture) and material transport to the construction site. This can be taken as the indicator value. This comes from a reliable source, based on national data that is less than 2 years old. The value is calculated based on a recognised/accredited methodology, so the average uncertainty score is 1.25, resulting in an uncertainty of 5% (Section 6.5). A summary of the uncertainty calculation is provided in Figure 25. This result can then be normalised to provide a value between 0 and 1 to be combined with other indicators within the Environmental category. For an indicator of this type, the ranked interpolation approach is most suitable (Section 6.6). An indicator value and associated uncertainty would then be calculated for each of the scheme options or material options being considered. It is likely that more novel approaches would result in a higher level of uncertainty.

¹²⁷ TII Carbon tool

Average emissions – 80mm deep dense asphalt = 13.65 kg CO₂/m²

Uncertainty quantification		
Criteria	Chosen result	Score
Source	Reliable	1
Geographical	National	2
Age	<2 years	1
Methodology	Recognised/accredited methodology	1
Average uncertainty score		1.25
Uncertainty quantification		5%

Carbon emissions = 13.65 +/- 5%

Figure 25 Determination of uncertainty for carbon emissions example

6.8.3. Sample DMIGF output

Once normalised values and uncertainties are determined for each indicator, the results for each category are generated for each approach / method / material being considered within the scope of the assessment. This provides a means to compare standard and innovative approaches across a range of categories simultaneously, considering not only average or expected values, but also the level of confidence in these figures. The potential increased risk related to technical performance, largely due to increased uncertainty associated with long term performance of certain approaches, is also presented. This provides a valuable decision making tool to identify various benefits of innovative or novel approaches. Figure 26 illustrates an example of the possible results format of the DMIGF. Single or multiple indicators within each category can be assessed over the reference period identified within the defined scope of the analysis. They feed into the assessment and the results are presented in a clear, user-friendly manner.



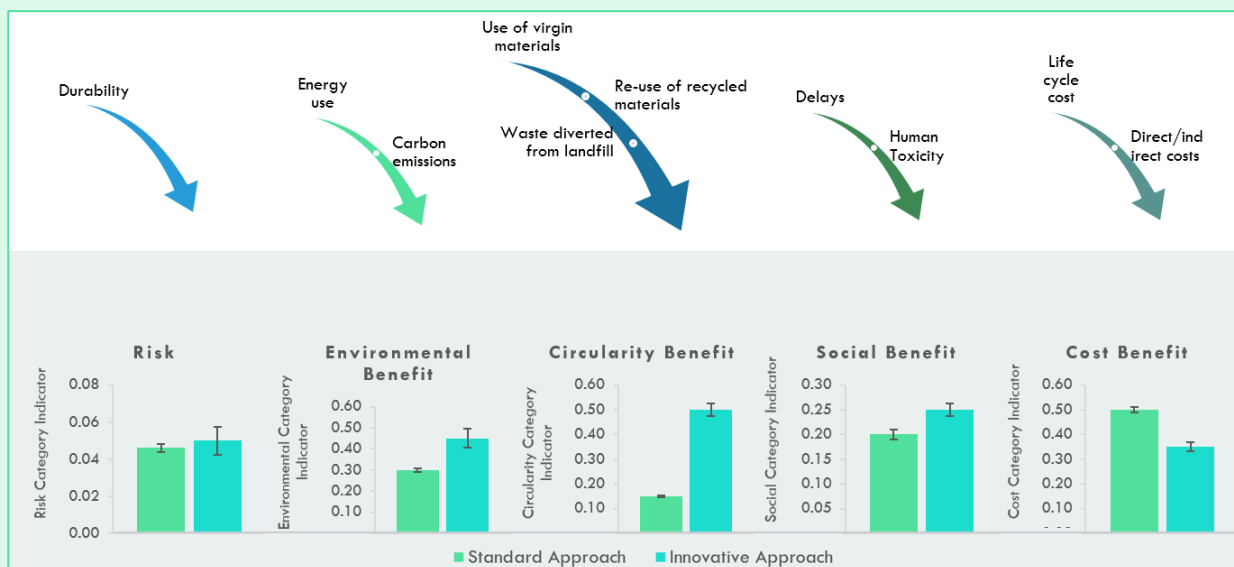


Figure 26 DMIGF prospective results format

6.9. Demonstration pilot

As the first step in the validation of the DMIGF, a methodology has been developed for the definition and calculation of the indicators corresponding to the DEMO 1 projects:

- The expanding of the capacity of a 13 km section of the Spanish A67 motorway, which runs through five municipalities, by the construction of an additional third lane and remodelling of five existing links.
- The replacing of the deteriorated surface course of around 200m of a Spanish national road (N-623) by Bioasphalt.

6.9.1. Methodology proposed

In this methodology indicators are determined by work unit (Figure 27). They are expressed using the ECOINVENT¹²⁸ database and subsequently converted to costs using the data expressed in RECIFE¹²⁹ (Figure 28) and PEF¹³⁰ (Figure 29). The following aspects of the project are considered:

1. Labour.
2. Machinery.
3. Materials, Manufacturing and Transportation to site.

WORK UNIT		RISKS				ENVIRONMENTAL				RE&CE				SOCIAL						COST		
		Technical performance	Safety	Durability	Maintenance related accidents	GHG Emissions	Energy use and/or generation	Water use	Environment at Toxicity Raw material expenditure	Waste generation	Waste diverted from landfill	Reuse and use of recycled material	Material available for next cycle	Noise pollution	Vibration	H & S of workers	Job creation	Delays	Human Toxicity	Direct/Indirect cost construction and maintenance	LCC	
LABOUR																						
MACHINERY																						
MATERIALS	MANUFACTURING																					
	TRANSPORT																					
MATERIAL EXECUTION COST																						
INDIRECT COST	%																					
DIRECT COST																						
WORK UNIT INDICATORS		IR ₁	IR ₂	IR ₃	IR ₄	IE ₁	IE ₂	IE ₃	IE ₄	IRC ₁	IRC ₂	IRC ₃	IRC ₄	IRC ₅	IS ₁	IS ₂	IS ₃	IS ₄	IS ₅	IS ₆	IC ₁	IC ₂

Figure 27 Work Unit expressed in indicators

¹²⁸ [ecoinvent - Data with purpose.](#)

¹²⁹ [CE Delft 7A76 Environmental Prices Handbook 2017 FINAL \(cedelft.eu\)](#)

¹³⁰ [Handboek Milieuprijzen 2023 \(cedelft.eu\)](#)



Impact category	Unit	Environmental price as weighting factor	Environmental price as external cost
Climate change	€/kg CO ₂ -eq.	€ 0.057	€ 0.057
Ozone layer depletion	€/kg CFC-eq.	€ 123	€ 30.4
Human toxicity	€/kg 1,4 DB-eq.	€ 0.0894	€ 0.0991
Photochemical oxidant formation	€/kg NMVOC-eq.	€ 1.15	€ 1.15
Particulate matter formation	€/kg PM ₁₀ -eq.	€ 39.2	€ 39.2
Ionizing radiation	€/kg kBq U ₂₃₅ -eq.	€ 0.0461	€ 0.0461
Acidification	€/kg SO ₂ -eq.	€ 7.48	€ 4.97
Freshwater eutrophication	€/kg P-eq.	€ 1.86	€ 1.86
Marine eutrophication	€/kg N	€ 3.11	€ 3.11
Terrestrial ecotoxicity	€/kg 1,4 DB-eq.	€ 8.69	€ 8.69
Freshwater ecotoxicity	€/kg 1,4 DB-eq.	€ 0.0361	€ 0.0361
Marine ecotoxicity	€/kg 1,4 DB-eq.	€ 0.00739	€ 0.00739
Land use	€/m ² a	€ 0.126	€ 0.0845

Figure 28 RECIPE Indicators EU

Naam Milieuthema PEF	Eenheid	Milieuprijs* per eenheid, NL	Milieuprijs* per eenheid, EU27
Klimaatverandering	kg CO ₂ -eq.	€ 0,130	€ 0,130
Ozonlaagaantasting	kg CFC-11-eq.	€ 29,1	€ 29,1
Straling	kBq U235-eq.	€ 0,00071	€ 0,00071
Smogvorming, menselijke gezondheid	kg NMVOC-eq.	€ 1,40	€ 1,48
Fijnstofvorming	Disease incidence	€ 1.937.047	€ 890.182
Verzuring	mol H ⁺ -eq.	€ 2,01	€ 2,04
Vermesting, zoetwater	kg P-eq.	€ 5,53	€ 3,74
Vermesting, zoutwater	kg N-eq.	€ 14,25	€ 14,25
Vermesting, land	mol N-eq.	€ 0,344	€ 0,331

* Dit betreft de milieuprijs per eenheid in de centrale variant.

Figure 29 PEF Indicators Netherlands

6.9.2. Indicators definition

Table 7 presents the formula used to define each indicator. A very extensive study has been carried out, which includes several indicators from each of the five categories that have been defined in the DMIGF: risk, environmental, circularity, social and cost.



Table 7 Indicators Definition

RISKS	Technical performance	Probability of failure * Direct Cost / Total Cost
	Safety	Probability of Safety * Direct Cost / Total Cost
	Durability	Probability of Durability * Direct Cost / Total Cost
	Maintenance related accidents	Probability accidents € h/accidents /Total Cost
ENVIROMENTAL	GHG Emissions	Total € Kg CO2 / Total Cost
	Energy use and/or generation	Total € kW /Total Cost
	Water use	Total € m3 /Total Cost
	Environmental Toxicity	*
RE&CE	Raw material expenditure	Total € Raw material expenditure / Total Cost
	Waste generation	Total € Waste generation / Total Cost
	Waste diverted from landfill	Total € Waste diverted from landfill / Total Cost
	Reuse and use of recycled material	Total € Reuse and use of recycled material / Total Cost
	Material available for next cycle	Total € Material available for next cycle / Total Cost
SOCIAL	Noise pollution	Total € Machinery > 80 Db / Total Cost
	Vibration	Total € Machinery > 1,15 m/s / Total Cost
	H & S of workers	Total € H&S / Total Cost
	Job creation	Total € Labour / Total Cost
	Delays	Total (0,60€/día)1000€ /Total Cost
	Human Toxicity	30.000 € / DALY
COST	Direct/Indirect cost construction and maintenance	Total Cost /(6% + 2%*20) Total Cost
	LCC	(Total Cost + (2%*20* Total Cost)) / Total Cost
	Residual value	(Total Cost -(2%*20 Total Cost) / Total Cost

Environmental toxicity is calculated considering the partial contribution of several components, which are presented in Figure 30.

* Environmental Toxicit																	
Particulate matter formation		Ionizing radiation		Acidification		Freshwater eutrophication		Marine eutrophication		Terrestrial ecotoxicity		Freshwater ecotoxicity		Marine ecotoxicity		Land use	
Kg PM ₁₀ -eq	€/Kg PM ₁₀ -eq	Kg kBq U235-eq	€/Kg kBq U235-eq	Kg SO ₂ -eq	€/Kg SO ₂ -eq	Kg P-eq	€/Kg P-eq	Kg N	€/Kg N	kg 1,4 DB-eq	€/kg 1,4 DB-eq	kg 1,4 DB-eq	€/kg 1,4 DB-eq	kg 1,4 DB-eq	€/kg 1,4 DB-eq	m ² a	€/m ² a

Figure 30 Components Environmental Toxicity. Source RECIPE and PEF.

6.9.3. Sample Indicators for the installation of bioasphalt

As an example of application of the proposed methodology, the indicators corresponding to the installation of bioasphalt are presented below, in Figure 31 to Figure 36.



Figure 31 Cost Data of Work Unit

Figure 32 Risks Data of Work Unit to Risks Indicators

Figure 33 Environmental Data of Work Unit to Environmental Indicators

Figure 34 RE&CE Data of Work Unit to RE&CE Indicators

Figure 35 Social Data of Work Unit to Social Indicators

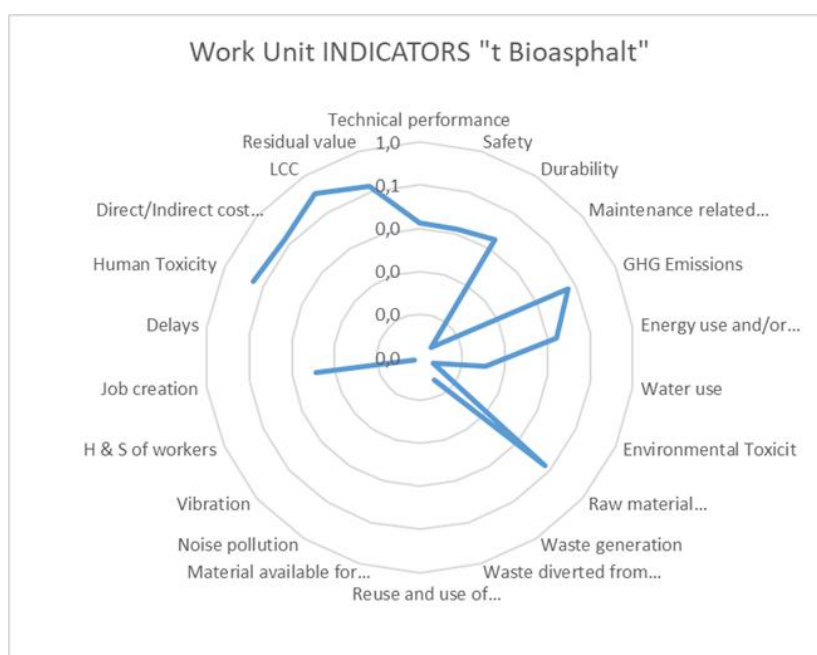
[illegible]

Figure 36 Cost Data of Work Unit to Cost Indicators

Table 8 summarizes the values of the indicators corresponding to the bioasphalt installation work unit. The results are also presented in a graph, in which the influence of each of the indicators can be seen more easily.

Table 8 Work Unit Indicators. Installation of Bioasphalt

RISKS	Technical performance	0,0131
	Safety	0,0126
	Durability	0,0176
	Maintenance related accidents	0,0000
ENVIRONMENTAL	GHG Emissions	0,0630
	Energy use and/or generation	0,0167
	Water use	0,0003
	Environmental Toxicity	0,0000
RE&CE	Raw material expenditure	0,0729
	Waste generation	0,0000
	Waste diverted from landfill	0,0000
	Reuse and use of recycled material	0,0000
	Material available for next cycle	0,2356
SOCIAL	Noise pollution	0,0000
	Vibration	0,0000
	H & S of workers	0,0000
	Job creation	0,0027
	Delays	0,0000
	Human Toxicity	0,1830
COST	Direct/Indirect cost construction and maintenance	0,1467
	LCC	0,3299
	Residual value	0,1414



This process would have to be carried out for all work units to obtain the final value of the indicators corresponding to the project of the replacing of the deteriorated surface course of around 200m of the Spanish national road (N-623) with Bioasphalt.

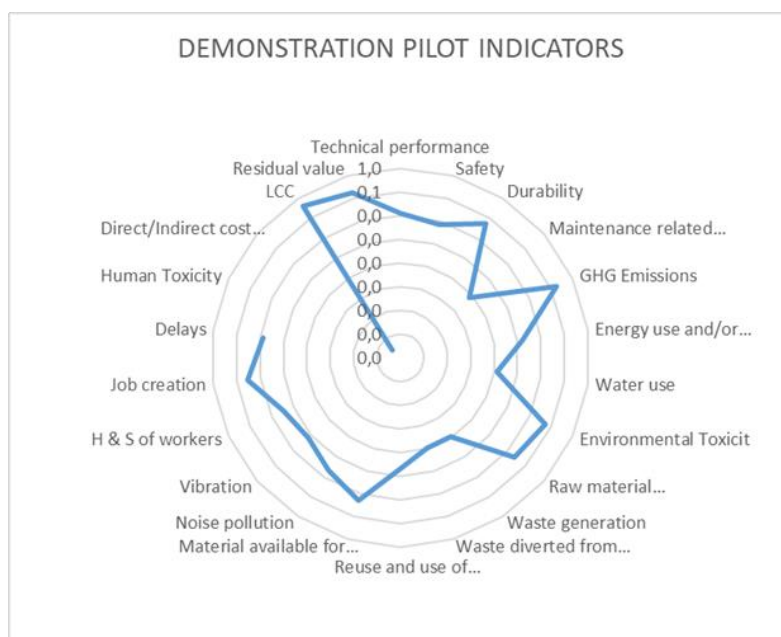


6.9.4. Demonstration Pilot Indicators. A-67 Project

In the case of the work corresponding to the A-67, since the project has already been carried out, the results have been obtained from the work unit indicators multiplied by its measurement and refer to the total cost of the project (Table 9).

Table 9 Demonstration pilot Indicators. A-67

RISKS	Technical performance	0,0122
	Safety	0,0071
	Durability	0,0508
	Maintenance related accidents	0,0001
ENVIRONMENTAL	GHG Emissions	0,1861
	Energy use and/or generation	0,0017
	Water use	0,0001
	Environmental Toxicity	0,0552
RE&CE	Raw material expenditure	0,0249
	Waste generation	0,0001
	Waste diverted from landfill	0,0001
	Reuse and use of recycled material	0,0005
	Material available for next cycle	0,0199
	Noise pollution	0,0045
SOCIAL	Vibration	0,0015
	H & S of workers	0,0029
	Job creation	0,0336
	Delays	0,0076
	Human Toxicity	0,0000
	Direct/Indirect cost construction and maintenance	0,0000
COST	LCC	0,4138
	Residual value	0,1773



6.9.5. Indicators in tender documents

The methodology proposed in point E.9.1 is very comprehensive and gives rise to specific values of the different sustainability indicators. Its incorporation into a public procurement process would mean that the administration would need to carry out a very exhaustive control of compliance with the indicators included in the contract during the work. In addition, this methodology is very useful to compare the indicators obtained in different projects at the level of technological selection.

In the tender procedure, the objective is to define a methodology that allows the inclusion of criteria that assess sustainability and circularity guaranteeing the maximum possible objectivity for all competing entities. For this reason, it is necessary that the criteria to evaluate indicators be collected a priori, perfectly defined and quantifiable so that all competing entities present comparable offers.

To calculate the contribution index of a structure to sustainability, it will be necessary to consider the sum of the contributions of each process involved in its design and construction, including the manufacture and transport of construction materials. Each process will be defined by a series of appropriate indicators to evaluate its contribution to the sustainability of the infrastructure.

Indicators can be mandatory or voluntary, and will have to be quantified and weighted, finding the most appropriate algebraic formula for calculating the sustainability index of both the project and the bidding company.

Indicators must be objective and easily evaluated and monitored. The tender documents must establish the evaluation system for each indicator, as well as the necessary evidence that the contracting company must present to verify that the requested requirements or specifications are met.

In the project phase and together with the technical specifications, indicators will evaluate the sustainability and circularity of the materials used in the work, the environmental requirements of the infrastructure, as well as social conditions and cost of the work.

The execution contract will include indicators that evaluate the sustainability of the construction company, which will also indirectly evaluate the sustainability of the infrastructure.

Some examples of indicators that may be incorporated in the tender documents are presented below:

- **Environmental indicators:**
 - Percentage of sustainable energy in the worksite.
 - Percentage of alternative fuels used.
 - EPD of materials used.
 - Percentage of vehicle fleet of the different classes according to emissions.



- **RE & CE indicators:**
 - Use of recycled materials.
 - Materials sent to landfill.
 - Materials that can be reused/recycled.
- **Social indicators:**
 - Workdays of long-term unemployed.
 - Percentage of long-term unemployed that are women.
 - Liability insurance.

Indicators may also be established to assess the management systems that the bidding company has, such as:

- Quality management system (EN ISO 9001),
- Environmental management system (EN ISO 14001/ Regulation (EC) No 1221/2009 (EMAS)),
- Energy management system (EN ISO 50001).

These management systems implemented in the bidding company must be demonstrated by the corresponding certificates issued after audits carried out by third parties accredited for this purpose.

6.9.5.1. Tender documents for the installation of bioasphalt

As part of the validation of the DMIGF, sustainable tender documents are being prepared for the rehabilitation of the road surface of a test section of 100 metres in length and the full width of the two-way carriageway Spanish national road N-623. The work includes the milling of the surface layer and the replacement of the road surface, using a conventional bituminous mixture for one of the lanes and a mixture with an experimental biobinder for the other lane.

The tender will have three types of contracts:

- Project drafting contract
- Contract for the execution of the works
- Technical assistance contract

Project drafting contract

The purpose of this document is to define the conditions and technical criteria to be followed during the drafting of the project. The project will incorporate sustainability and circularity indicators for the preparation of the report, the budget and the specifications, to use them for the evaluation of the offers. Guidelines for their presentation will also be included.

The Technical Specifications of the contract will include a description of the different works that will have to be carried out for the preparation of the project, and in those that must be



expressed through indicators, it will detail the indicators that will have to be determined and the way to calculate them.

Annex I presents an example of a contract scheme for the drafting of the project, where the works that must be expressed through indicators are detailed. This is a general scheme and could be applied to any infrastructure, considering in each case the particularities of each project.

In the case of the installation of bioasphalt, in addition to the work presented in the scheme, other specific tasks must be considered, such as traffic analysis, the sizing of the road surfaces and pavements, traffic solutions during the execution of the work, and signage, beaconing and defences.

The drafting of the project will involve the calculation of the different indicators by the planner and will give rise to the document that will include the technical specifications of the contract for the execution of the work.

Contract for the execution of the works

This contract will meet the needs described in the project by carrying out the works included therein, complying with the requirements specified in the Technical Specifications Document, including the circularity and sustainability indicators.

Since the bidding companies will be able to improve the values of the indicators present in the Technical Specifications Document, this contract will establish the evaluation and weighting system for each indicator, as well as the evidence that the company must present to verify that it complies with the values offered.

In addition, this contract will evaluate the sustainability of the construction company, through another series of indicators that will also be used to evaluate the offers.

Technical assistance contract

In the case of the installation of bioasphalt, it has been considered appropriate to include a technical assistance contract for the construction management, mainly due to the novelty of the incorporation of the indicators. Its main purpose is to ensure that the execution of the work is carried out in accordance with the established plans, specifications and regulations and, in this specific case, that the required sustainability and circularity indicators are achieved.

6.10. Roadmap to implementation

The proposed DMIGF will facilitate quantification and ranking of various standard and innovative approaches related to conceptual design, detailed design, and operation/use of elements and technologies related to transport infrastructure. Within each of the 5 categories, the DMIGF will provide a clear indication of the relative score of each considered option, along with a confidence level associated with each result.



As discussed in this deliverable, various European and National documents, incentives, existing frameworks and policies have fed into the development of the initial DMIGF draft. This will continue to develop throughout the course of the LIAISON project. Information and collaboration with LIAISON demo cases will strongly influence further development, as will stakeholder engagement and feedback. Based on inputs and feedback from the various sources described, the DMIGF will be finalised at the end of month 36 of the LIAISON project.

To ensure ongoing implementation of the DMIGF after the project is complete, it is vital to engage various stakeholders throughout the project, who have input into the final development and an understanding of the objectives and processes involved. The goal is for the DMIGF to be scalable and replicable so that it can be used in various formats by owners and managers depending on the type of project or scheme. It is envisaged that over time, the DMIGF will help inform policy, guidelines, standards, data collection and data sharing to make the process more robust. Increased data reduces uncertainties and can be used to demonstrate successes, thus informing future policies and standards. The envisaged roadmap to implementation is outlined in Figure 37.

Through collaboration and dissemination, it is essential to engage with end users and stakeholders through the course of the project to ensure ongoing implementation to achieve the maximum long-term impact of increasing circularity, reducing the use of virgin materials and reducing carbon emissions.



D1.1: LIAISON DMIGF Methodology – Initial version

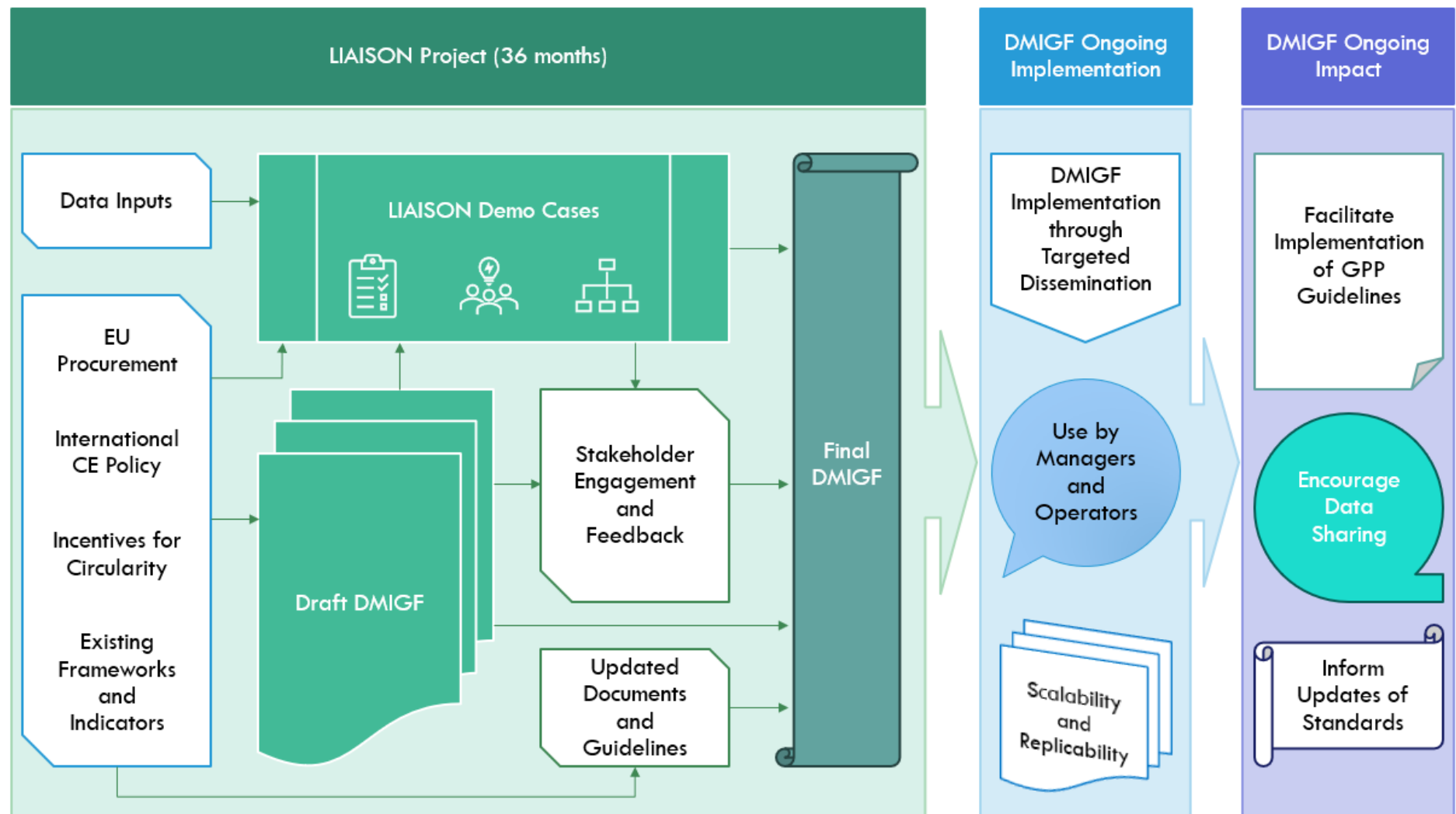


Figure 37 Roadmap to implementation



Funded by the European Union

6.11. Conclusion

This section illustrates the current state of play for the LIAISON DMIGF, provides a sample application based on dummy data, as well as an initial application for Demo 1 of the LIAISON project. The Roadmap to implementation within the project and beyond is finally presented.

Further development and refinement of the DMIGF will continue throughout the remainder of the LIAISON project as analysis of the Demo Cases progresses. To date, individual workshops have been held with each of the Demo Case leaders to discuss specific factors related to each study and ensure maximum success in incorporating Demo Case results within the DMIGF. Initial lists of KPIs to be quantified within each demo case have been prepared, and will be presented in the final version of the LIAISON DMIGF (month 36).



7. Deliverable Summary

This report summarises the results of LIAISON D1.1, relating to LIAISON tasks 1.1 and 1.2.

In Part 2, the current state of play in circularity of TI was evaluated. It was identified that a key barrier stems from the lack of data availability, data homogeneity, or data sharing across different TI sectors to allow quantification of circularity. LIAISON is delivering a digital framework to support the DMIGF which will be presented in D1.2. The goal here will be to alleviate this data barrier for the future of the DMIGF.

Part 3 of this report addresses implementation of circularity by TI administrators including case studies in the road and rail sector. Crucially, this section provided context to the DMIGF KPI categories with consideration of the Level(s) approach. A review was also performed of technical standards which lend themselves to innovation in TI construction and maintenance. Finally, an overview of procurement and supply chain incentives were provided in order to ensure the DMIGF outputs can be interpreted by and ideally, incorporated in future EU procurement, particularly for LIAISON Demo Case 1.

Section 4 addresses organization governance and regulatory incentives. Standards in this regard are considered in the context of circular procurement and business models.

The results presented in sections 3-4 highlighted and identified the form of the DMIGF presented in section 5. Workshops were also carried out during the first year of the project with demo case leaders and external stakeholders to seek feedback and tailor the DMIGF into an actionable framework. A sample application was provided for context, before applying the DMIGF to Demo Case 1. This application will be significantly enhanced in the next 12 months of the project, together with the other LIAISON demonstrators, in order to refine the DMIGF as part of the Roadmap to Implementation presented.

Further development and refinement of the DMIGF will continue throughout the remainder of the LIAISON project as analysis of the Demo Cases progresses. To date, individual workshops have been held with each of the Demo Case leaders to discuss specific factors related to each study and ensure maximum success in incorporating Demo Case results within the DMIGF. Initial lists of KPIs to be quantified within each demo case have been prepared, and will be presented in the final version of the LIAISON DMIGT (month 36).



Annex I

CONTRACT SCHEME FOR PROJECT DRAFTING

1 PURPOSE OF THE CONTRACT

The purpose of this document is to define the conditions and technical criteria to be followed during the execution of the work necessary for the drafting of a project in which circularity and sustainability indicators will be incorporated.

2 DOCUMENTATION AVAILABLE TO THE PLANNER

The entity responsible for the contract will provide the Planner with all available documentation relating to the administrative and technical background necessary for the preparation of the project

3 CONTRACT EXECUTION TIME

The execution time of the works will be specified.

4 ESTIMATED BUDGET OF THE CONTRACT

The estimated value for the tendering of the works for the execution of the project object of this contract will be specified.

5 MANAGEMENT OF WORKS

The entity responsible for the contract will appoint a Contract Manager, who will perform the coordinating function and will establish the criteria and general lines of the Planner's work, specifying his functions.

6 STAFF AND OFFICE OF THE PLANNER

6.1 Personal resources for drafting the project

The Planner will be the person in charge of coordinating with the Contract Manager the development and possible incidents during the life of the Contract. The qualifications and experience required of the Planner will be specified.

6.2 Material resources

The Planner must have all the necessary resources for the correct execution of the works.



7 REPORTS ON THE DEVELOPMENT OF THE WORKS

The Contract Manager may require the Planner to hold meetings and/or reports on the general progress of the works, to verify compliance with the requirements included in this contract for the drafting of the project in question.

8 DESCRIPTION OF THE WORKS TO BE CARRIED OUT

The project will be drawn up following the existing regulations and instructions regarding the drafting of projects.

8.1 Current situation and proposed actions

The current state of the infrastructure subject to the contract will be described. To this end, the Planner will carry out a compilation and synthesis of the available documentation, preparing a proposal with the actions that are deemed necessary and that will constitute the object of the Project.

8.2 Origin of materials

This will be expressed using the following **Waste and Circularity indicators**:

- Raw material expenditure: Cost of materials / Unit cost of work
- Reuse and use of recycled material: Cost of recycled material / Unit cost of work
- Material available for the next cycle: Cost of reusable material / Unit cost of work

8.3 Environmental integration

The preventive and corrective measures and environmental integration of the Project must be defined, adapted to the scope of the planned actions, using the following **environmental indicators**:

- GHG emissions: Cost of Kg of CO₂ produced by the machinery and the production of materials/ Unit cost of work
- Use and/or generation of energy: Cost of energy used by the machinery and the production of materials/ Unit cost of work
- Use of water: Cost of water used in the unit of work/ Unit cost of work.
- Environmental toxicity:
 - Formation of particles/ Unit cost of work
 - Acidification/ Unit cost of work
 - Terrestrial ecotoxicity/ Unit cost of work
 - Freshwater ecotoxicity/ Unit cost of work
 - Use of land/ Unit cost of work

8.4 Coordination with other organisations and services

All actions of all organisations and services involved in the execution of this contract must be coordinated.



8.5 Work plan

A Work Plan will be drawn up, stating that this schedule will be merely indicative.

8.6 Justification of prices

The calculation of prices for the different work units will be based on the determination of the precise costs for their execution and will be expressed through **circularity and sustainability indicators**, divided in the following categories:

- Risk
- Environmental
- Waste and circularity
- Social
- Cost

8.7 Construction and demolition waste management study

The project must include a Construction and Demolition Waste Management Study that includes the following **Waste and Circularity indicators**:

- Waste generation: Waste cost / Work Unit Cost
- Waste diverted to landfill: Landfill material cost / Work Unit Cost
- Reuse and use of recycled material: Cost of recycled material / Work Unit Cost
- Material available for the next cycle: Cost of reusable material / Work Unit Cost

8.8 Evaluation of tests

Any operation, work, test, etc., that is necessary to carry out for the correct drafting of the project will be the responsibility of the Planner.

9 OTHER OBLIGATIONS OF THE PLANNER

9.1 Information management

The Planner shall be responsible for obtaining the information, permits and official or private licenses required for the execution of the commissioned works, as well as the payment of fees, compensations and other indemnities that may be applicable for the execution of the Contract.

The Planner shall undertake to maintain as confidential all information supplied by the contracting entity for the preparation of the project drawn up within the framework of this Contract.



9.2 Prevention of occupational risks in work

The Planner must comply with the provisions of the regulations and instructions on health and safety applicable in general, assessed with the following **social indicators**:

- Noise Pollution: Cost of machinery that produces > 80 dB/Unit Cost of Work
- Vibration: Cost of machinery that produces > 80 Hz/Unit Cost of Work
- Safety and health of workers: Health and safety cost of the project/Unit Cost of Work
- Human toxicity: DALY cost of material * DALY cost/Unit Cost of Work

9.3 Cartographic work

The cartographic and topographic work that is necessary for the correct design of the project will be carried out.

10 COMPUTER CALCULATIONS

For the acceptance of calculations performed with a computer, the following information must be included:

- Description of the program used.
- Hypotheses and simplifications made.
- Design constants and equations used, with a clear distinction between input data and program calculations.
- General and detailed diagram and written, step-by-step description of all calculations.

Lists of results that are not preceded by the corresponding explanation will not be accepted.

The calculation of the following **risk indicators** must be included:

- Technical Performance: Probability of Failure per Cost of the Unit of Work
- Safety: Probability of Failure per Cost of the Unit of Work
- Durability: Probability of Failure per Cost of the Unit of Work

11 PRESENTATION AND EDITING OF THE PROJECT

The required method for the presentation and editing of the project must be specified.

