UIC SUSTAINABILITY

Circular practices in the railway and ways forward

REUSE Project final Report

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Ackownledgments

Authors

ZAG - Slovenian National Building and Civil Engineering Institute

- Dr Sebastjan Meža,
- Dr Stanislav Lenart,
- Dr Alenka Mauko Pranjić,
- Dr Ana Mladenović,

Supervisors and coordinators

- Lucie Anderton, Head of UIC Sustainability,
- Isabelle De Keyzer, UIC Sustainability Advisor, Project manager of REUSE.

Editors

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Members of the REUSE Project group

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Contents

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List of acronyms and abbreviations

Acronym	Full name
AFNOR	French Standards Institute
BSI	British Standards Institution
CE	Circular Economy
CEAP	Circular Economy Action Plan
EC	European Commission
ECI	Environmental Cost Indicator
EU	European Union
GHG	Greenhouse gas
GPP	Green public procurement
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
NRAs	National Road Authorities
RREE	Roadmap to a Resource Efficient Europe
SRM	Secondary raw materials
UIC	International Union of Railways / Union Internationale des Chemins de fer
WFD	Waste Framework Directive
ZAG	Slovenian National Building and Civil Engineering Institute

Executive summary

This report addresses the challenges and opportunities the railway industry is faced with when trying to shift from linear towards a more sustainable circular economy (CE).

In the first part of the report, fundamental CE principles are presented, building upon the theoretical notion of circularity. The overall perspective is given through the literature review; first of strategic documents such as EU policy documents and the standpoint of the scientific community in terms of sustainable design. The concept of green public procurement (GPP) is outlined as one of the significant enablers of the CE.

The second part of the report summarises the output of the primary research, presenting the perspective of the rail industry. The research, in the form of 16 structured interviews, was conducted among railway stakeholders, representing 12 businesses from 11 European countries. It has been realised that the vast majority of interviewees support the idea of the CE, and in particular of the reuse of key raw materials, as they are aware of the challenge of the limited amounts of natural resources, the high environmental footprint that linear economy is leaving behind, and the economic potential that remains untapped with the disposal of materials after the primary life cycle.

The concluding part of the report is devoted to presenting the best practices implementing CE principles, offering the readers possible answers to the question, “where and how to start implementing the CE?”

List of Figures

1. Introduction

Efforts towards a cleaner and greener future have been emerging recently in all segments of our lives. The urgency to react to the challenges posed by climate change, the ever-increasing demand for resources, population growth, and loss of biodiversity has been recognized globally with strategic documents such as the Paris Climate Agreement not only at European level (European Union (EU) but also at national and local levels. In the EU, sustainable development has been high on the list of priorities for a long time.

Recently it is being implemented both in terms of legislation with directives, and on the operational field via financial subsidies and project funding opportunities (i.e., Green Deal, Renovation wave, Circular Economy Action Plan, European Industrial Strategy)[1][2][3][4]. The claim can be supported by the fact that the European Commission (EC) provides substantial support for projects. Over € 100 billion in financial support and technical assistance will be available over the 2021 - 2027 period in support of a green economy.

Until recently, a large amount of effort was focused primarily on reducing greenhouse gas (GHG) emissions. Still, studies indicate that relying solely on energy efficiency and switching to renewable energy will only address 55% of global GHG emissions. On the other hand, it has been indicated that by adopting circular economy (CE) principles, we can reduce a significant proportion of the remaining 45%[5]. For example, circulating products and materials - instead of producing new ones - can help cut energy demand, by maintaining the energy that went into making them. Further, the CE is beneficial from environmental, economic and social points of view. According to a recent study from Roland Berger[6], the introduction of innovative CE business models along the entire construction and renovation value chain works could lead to a € 240 billion market share.

1.1. Goals

To address the environmental challenges listed in the introduction, the International Union of Railways (UIC) initiated the REUSE project to which this report refers to.

The REUSE project was launched in January 2019 and finished in Spring 2021. It was funded and conducted by a working group of six UIC members[7]. The group met on regular occasions to define the scope of the project and identified the key materials that are posing challenges in terms of sustainable management of resources while at the same time embedding the biggest opportunities in terms of reuse, recycling and offering the highest gain opportunities, namely as they allow important savings in CO_2 emissions, natural resource use and costs.

The key materials identified in the early stages of the project are ballast, steel (rail, etc.) and concrete sleepers. The group shared the circular economy practices that have been put in place in their respective companies with relation to the sustainable management of those key materials.

To enable UIC members overall to take advantage of those findings and success stories, the working group decided to draft a report to provide starting points about the CE for the railway stakeholders to build upon when preparing the strategic documents for their organizations.

The report responds to the following questions:

- *Why consider CE in the railway sector?*
- *Which are the relevant CE concepts, strategies and standards?*
- *Where to find appropriate theoretical know-how?*

[1] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
[2] https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en
[3] https://ec.europa.eu/environment/strategy/circular-economy-action-plan_en
[4] https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en
[5] Completing the picture how the circular economy tackles climate change, 2019, Ellen Macarthur Foundation
[6] How circular economy can drive greater sustainability and new business opportunities in construction
[7] Deutsch Bahn, INFRABEL, ProRail, RFI, SNCB/NMBS, SNCF Réseau

- *How other similar industries adopt the CE?*
- *Which are the lessons learned so far by the early adopters in the railway community?*
- *How to raise the level of awareness about the opportunities the CE offers?*

1.2. Methodology

This research was completed in the following 4 stages:

1. Written survey

   A written survey was completed by the UIC member partners of the project in 2020 (Section 5.1). 11 experts belonging to 11 different companies provided written information about their approach to CE.

2. Desktop research

   A thorough review of existing literature was carried out, reviewing scientific research papers, the strategic railway documents that were publicly available, and the results of various national and EU funded projects (Section 2).

3. Interviews

   Interviews were conducted using a set of questions drafted by the Slovenian National Building and Civil Engineering Institute (ZAG) (Section 5.2), reviewed and supplemented by the REUSE working group. Interviews were held between January and March 2021. Overall, 16 interviews were conducted with representatives of 11 organizations[8], coming from 11 European countries[9]. It is estimated that this is a sufficient number of responses to provide a representative picture of the current status of the CE in the railway sector.

4. Interactive Workshop

   The findings of the interviews were summarised and used as reference points for discussion in the REUSE workshop (section 5.3). The workshop, held on 15 April 2021, was attended by some 80 representatives from 19 railway industry stakeholders based in 35 different countries around the world. This event provided an additional source of information with small working group discussions used to confirm and expand upon findings.

1.3. Target audience

The project is intended to assist the UIC's global membership of railway operators, infrastructure managers and integrated railway companies in their day-to-day operations regarding the sustainable management of resources. In addition, it should consider the views of other relevant stakeholders, including but not limited to manufacturers, regulatory bodies, policy makers, research institutions.

[8] ADIF/ADIF AV, CFL, Deutsche Bahn AG, InfraBel, Irish Rail, ProRail, Network Rail, SBB, Trafikverket, Slovenske Železnice, SNCF RESEAU

[9] Spain, Luxembourg, Germany, Belgium, Ireland, The Netherlands, United Kingdom, Switzerland, Sweden, Slovenia , France

2. Background

CE principles in the railway sector have been established through previous research and a number of guidance documents have been published in recent years. However, their uptake in practice is just starting to gain momentum. Barriers to a more efficient implementation of the CE exist, but there is a small but growing body of documented best practices on how to overcome them. To better understand why putting efforts into changing the traditional linear model into the circular one, this chapter provides theoretical background to the CE.

2.1. From linear to circular

There is no unified definition of the CE paradigm, however there is a common goal standing behind the CE. In essence, the idea is to reduce the consumption of primary raw materials in a way that the materials do not get discarded as waste but are treated as raw materials with inherited value. Furthermore, the CE is not only about addressing the materials as such, but also about helping the organizations to “turn things on their head” as they have to completely re-think how resources are managed in order to attain financial, environmental and social benefits, in both short and long -term perspectives. The Ellen MacArthur Foundation, as one of the key protagonists, broadly defines the CE as a set of principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems. It promotes the idea that the CE should seek to rebuild capital, whether this is financial, manufactured, human, social or natural. This ensures enhanced flows of goods and services[10]. The principles of CE can also be presented graphically with the “9R strategy” (Table 1).

Table 1: CIRCULARITY AND NINE ‘RS’[11]

Circular economy	Strategies		
	Smarter product use and manufacture	R0 Refuse	Make product redundant by abandoning its function or by offering the same function with a radically different product.
		R1 Rethink	Make product use more intensive (e.g., by sharing product).
		R2 Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials.
Increasing circularity	Extended lifespan of products and its parts	R3 Reuse	Reuse by another consumer of discarded product which is still in good condition and fulfils its original function.
		R4 Repair	Repair and maintenance of defective product so it can be used with its original function.
		R5 Refurbish	Restore an old product and bring it up to date.
		R6 Remanufacture	Use parts of discarded product in a new product with the same function.
	Useful application of materials	R7 Repurpose	Use discarded product or its parts in a new product with a different function.
		R8 Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality.
Linear economy		R9 Recover	Incineration of material with energy recovery.

[10] https://www.ellenmacarthurfoundation.org/circular-economy/concept
[11] https://www.ellenmacarthurfoundation.org/assets/galleries/CEinaction-_Activity06-nine-Rs-6R3_from-graham-081217.pdf

2.2. EU starting points and policies

The “EU action plan for the Circular Economy” defines the sectors where the transition to a circular economy is particularly meaningful. The priority areas include plastics, food waste, critical raw materials, biomass and bio-based products and most importantly in relation to the scope of this document, construction and demolition waste. Those materials and related sectors need to be addressed in a targeted way, to ensure that the interactions between the various phases of the cycle are fully taken into account along the whole value chain[12]. That is to say, a number of sectors face specific challenges in the context of the CE, because of the specificities of their products or value-chains, their environmental footprint and even their dependency on material from overseas. Also, the document highlights construction and demolition waste (CDW) as one of the major focuses of the CE, since construction and demolition works produce over 1/3 of all waste in Europe. Construction and maintenance of the railway assets also produce a lot of waste falling in this category.

In 2019, Europe adopted the “European Green Deal”, a new resource-decoupled growth strategy committing EU which goes a step beyond also tackling climate and environmental-related challenges. The European Green Deal consists of several blocks, one of them being “A new Circular Economy Action Plan (CEAP)”[13] published in 2020. This document defines seven value chains where the transition to the CE is crucial. Of particular relevance is the growing waste stream of the construction sector, including the construction, demolition and renovation of the built environment.

The EC has declared the year 2021 as “The European Year of Rail”[14] which also complements its “Sustainable and Smart Mobility Strategy”[15]. The Sustainable and Smart Mobility Strategy and circular economy, resource efficiency policy are mainly connected in building smart, sustainable and efficient infrastructure, supported by digitalisation.

The “Waste Framework Directive” (WFD)[16] lays down measures to protect the environment and human health by preventing or reducing the generation of waste. It considers the adverse impacts of the generation and management of waste and reducing overall impacts of resource use and improving the efficiency of such use. The WFD is a crucial instrument for the transition to a circular economy and for guaranteeing the Union’s long-term competitiveness. The document formally defines the processes related to waste management, including the hierarchy (Figure 1) of how they should be implemented.

Figure 1: Waste management hierarchy[17]

[12] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614
[13] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN
[14] https://ec.europa.eu/transport/modes/rail/news/2020-03-04-promoting-sustainable-mobility_en
[15] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0789&from=EN
[16] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02008L0098-20180705
[17] https://ec.europa.eu/environment/waste/framework/)

2.3. Designing the CE

A shift towards circular design is far from trivial as not only technical adaptations have to be considered, but more importantly, a completely new mind-set has to be put in place. When designing a product, its impact on society or the environment during its entire lifecycle must be taken into consideration, and its negative effects must be limited, while quality and performance should not suffer. To minimize the impact in contrast to the linear 'take, make, dispose', circular design looks for materials to be repeatedly recovered and reused for as long as possible already in the early project or product design stages.

The notion of design is understood in its broadest sense including planning of activities across the whole product lifecycle. It is an important enabler of CE, as it impacts all stages in the material lifecycle (Figure 2), starting with raw material extraction, production, processing, etc. As the design decisions may influence significantly the overall environmental impact, it is essential that studies such as life cycle assessment (LCA) qualifying the product's environmental impacts from extraction of raw materials to waste treatment, are being considered[18].

Figure 2: The CE material life cycle[19]

To steer, support and measure design tasks, standards provide organizations with guidance on which actions to take, national norms launched in Great Britain and France can be referred to, such as " BS 8001:2017 - Framework for implementing the principles of the CE in organizations − Guide" was developed and launched in May 2017 by the British Standards Institution (BSI)[20]. After this, the French Standard Institute (AFNOR) launched "XP X 30-901 CE project management system - Requirements and guidelines" in October 2018[21].

[18] Whole life cycle analysis - whole Life Costing; EN-ISO 15686-5
[19] https://srip-circular-economy.eu/
[20] BS 8001:2017 - Framework for implementing the principles of the circular economy in organizations. Guide
[21] https://www.boutique.afnor.org/standard/xp-x30-901/circular-economy-circular-economy-project-management-system-requirements-and-guidelines/article/919346/fa194960

2.4. Green public procurement and circular economy

Public procurement in general can be defined as a set of processes through which government departments, regional and local authorities or bodies govern purchasing of works, goods or services. Most current procurement processes and practices support the traditional linear production model. Opportunities for reuse or recycling are rarely assessed at the procurement stage unless the purchased item has an obvious residual value. When it comes to costs one is faced with the following question: what does the price include? It is one thing to speak about the money that is "physically" transferred from entity A to entity B, and another to consider more comprehensive "external costs" incurred by the degradation of the environment.

An alternative to traditional "money-first" procurement is a process often denoted as "green (public) procurement" (GPP). In the GPP paradigm all costs which can be closely associated with the first set of orientations in the 9R strategy (refuse, rethink, reduce) need to be considered. To set the scene, the GPP can be thought of as "a process by which public authorities seek to procure goods, services and works that have a lower environmental impact throughout their life cycle than goods, services and works with the same primary function that would otherwise be procured"[22], whereas taking into account the longer-term impacts of any purchase and also whether the purchase is necessary in the first place. Although the emphasis in this chapter is on public sector procurement, the methodology can also be applied to the private sector.

Both literature review[23] and the survey results indicate that the price is most often the key deciding factor in the procurement decisions.

2.5. Circular economy in comparable industries

In terms of sustainability of mobility, railways are often compared to road, aviation and maritime transport. Studies often focus on environmental cost incurred by the actual act of moving people and resources from point A to B (i.e., air quality, CO_2 emissions, noise, water pollution...). It is however important not to ignore the impact of underlying infrastructure construction and renovation activities. This is especially true, due to the large amount of material used in infrastructure construction. In the Swedish transport infrastructure, an estimated 3 million tonnes of CO_2 equivalent are being generated by construction, operation and maintenance of the infrastructure, not taking into consideration the traffic itself[24]. Most of the emissions occur during material production and, hence, a life cycle perspective is necessary in order to evaluate emissions from transport infrastructure (Figure 3).

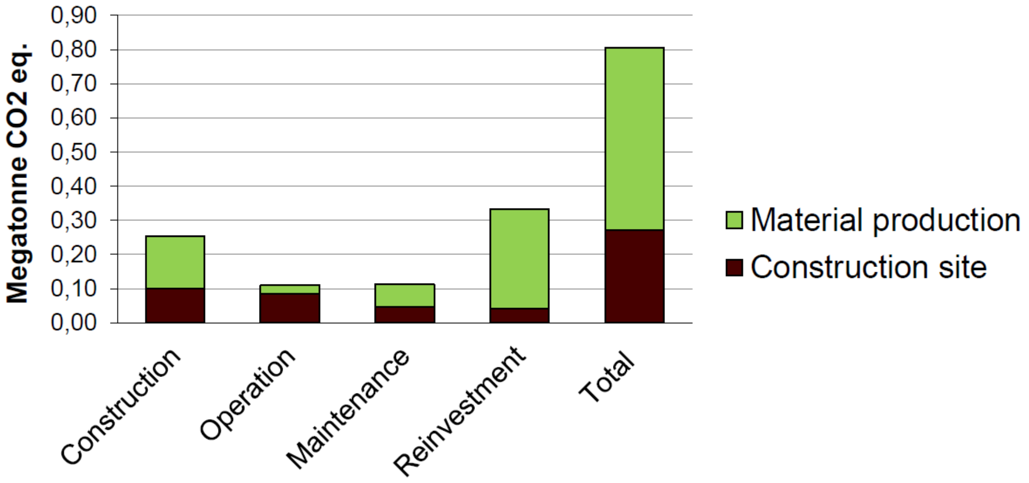


Figure 3: Annual direct and indirect emissions from construction, operation and maintenance of state-owned roads[25]

[22] https://ec.europa.eu/environment/gpp/versus_en.htm
[23] A systematic literature review of the transition to the circular economy in business organizations: Obstacles, catalysts and ambivalences
[24] Based on: Liljenström, Toller, Åkerman and Björklund 2019, EJTIR 19(2)
[25] Based on: Liljenström, Toller, Åkerman and Björklund 2019, EJTIR 19(2)

As a matter of fact, the construction industry is one of the main resource intensive sectors, consuming more than 50% of extracted natural resources. According to the Roadmap to a Resource Efficient Europe (RREE)[26], more than 50% of all extracted materials for construction sector could be saved through better construction practices.

An example of the CE implementation in road infrastructure was identified by various National Road Authorities (NRAs) in their strategies of asphalt treatment and production. Many road authorities are applying principles of the CE, through recycling of reclaimed asphalt (RA), extension of the service life of their assets (preventive maintenance), and the reuse of wastes in asphalt pavements. In detail, asphalt mixture that incorporates RA contains less fresh bitumen and virgin aggregates in comparison to the conventional asphalt mixture[27].

CE is also being considered by the aviation industry[28]. For example, eco-friendly design of airports using modular design, the production of planes that can easily be disassembled after the end of use and more durable components installed in jet engines. An example of CE in aviation is “Circular lighting at Schiphol Airport”[29]. The principle is simple: instead of buying light bulbs, Schiphol Airport is paying for the light. Philips developed sustainable light bulbs, which comply with the stringent CE requirements. These light bulbs have been specifically designed to allow fast and easy repair or replacement.

[26] https://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm
[27] European National Road Authorities and Circular Economy: An Insight into Their Approaches
[28] https://www.icao.int/environmental-protection/Documents/ecoairports/Final%20Airport%20Eco%20Design%20Overview.pdf
[29] https://www.lighting.philips.com/main/cases/cases/airports/schiphol-airport

3. Best practice material handling

This chapter focuses on the circularity of individual physical components and materials, identifying the best practices, challenges, and opportunities of material recycling.

The survey replies indicate that the best practices in terms of material circularity can be classified in four categories. This part of the report is therefore organised accordingly. First, the best practices in terms of material treatment logistics are summarised. The second part presents the reuse and recycling best practices for the core group of rail materials (ballast, sleepers, rails, and switches). The third lists possibilities within the rolling stock, and in the fourth presents the possibilities in the support materials (IT equipment, fluids, clothes…).

3.1. Material workflow organization

During the preparation of the questionnaire and during the interviews, we strived for the clearest possible division between the concepts of “reuse” and “recycling”. Despite the fact that the interviewees seemed well acquainted with the fundamental notion differences, from theoretical point of view, they nevertheless pointed out that in practice, it is difficult to distinguish between the two concepts. Indeed, if at first glance, the notions may sound similar, they represent completely different concepts. Namely, completely different sets of rules need to be taken into consideration when materials are recycled in any way, or if they are reused.

As the materials need to be inspected in detail, tested and, last but not least, given an expert’s opinion, experts have to verify that even after processing, the materials are of the same quality as the initial raw materials. In this respect, centralized waste collection proves to be an example of best practice.

For example, **Network Rail**, described the rail recycling centre at Whitemoor where every day, track panels, sleepers, rails, small steel components and switches and crossings units are delivered to the facility (Figure 4). Typically, 40 to 50 wagons arrive each week, but sometimes as many as 90 to 100.

Figure 4: Whitemoor Aggregate Handling Depot[30]

The materials are graded and sorted into what can be reused on the network and what can be sold on to approved external dealers[31]. Before the materials are auctioned, they are treated according to standards i.e., the ballast is cleaned to remove all hazardous materials. A dedicated team has been established to co-ordinate the sale and reuse of any redundant railway assets, ensuring all sales are monitored, measured and controlled (Figure 5).

[30] Presentation on REUSE workshop
[31] https://www.networkrail.co.uk/stories/recycling-recovered-railway-materials-at-our-whitemoor-facility/

Figure 5: Ballast treatment facility[32]

By the same token, **PRORAIL** reminded us about the market size differences. They indicated it would be a good idea to have a common European market, especially for smaller and more expensive specialized parts. However, because some elements are not standardized, even a small technical detail can lead to them being incompatible and thus not suitable to be exchanged among countries (e.g., small differences in sleepers prevent use of used Dutch sleepers in Germany).

SNCF RESEAU on the other hand, raised the issue of the organization of construction and reconstruction in terms of location. As transport is a contributing factor to both costs and environmental footprint, the centralized approach has to be carefully planned during the design stages. An inventory of potentially reusable products needs to be conducted in the "donating project" and simultaneously the "receiving projects" need to be identified in close proximity both geographically and temporally.

Another important issue that needs to be considered is material labelling and monitoring. An accurate and up to date datasets of all purchased material can lead to significant material and cost reductions already in the construction stage, but also after the end of the service life of the individual materials or components. To address the identified opportunities and challenges the interviews pointed out the potential in IT support tools[33][34].

NETWORK RAIL pointed out their internal stock market application named 'Surplus App'. The app is aimed at facilitating the internal redistribution of assets internally within the company, in order to create financial efficiencies and drive greater sustainability. Currently £40m worth of assets are posted onto the app.

32 https://www.agg-net.com/news/new-national-materials-recycling-centre-for-network-rail
33 https://madaster.com/platform/
34 https://railwayrecycling.co.uk/railway-sleepers/

DB also indicated the importance of the environmental impact studies in the design phase. The company is evaluating the impacts of raw material impacts with a self-made tool named **Green Evaluation Tool** using three indicators: (1) cumulated raw material expenditure in t, (2) cumulated energy consumption in GJ, and (3) global warming potential in t CO_2.

3.2. Railway track materials

This section presents best practices regarding recycling and reuse of three major rail components.

3.2.1. Ballast

The aggregate ballast layer is a major structural and drainage component of railroad track that is known to degrade over time. Progressive degradation increases the fine-grained content of the ballast layer through particle breakage and abrasion or from external sources, such as subgrade or foreign material. The point at which ballast should be cleaned of these materials to avoid significant problems for drainage, track geometry, or ride quality is not well known[35].

A clean, elastic and homogeneous ballast bed is an essential pre-requisite for the wheel-on-rail system to function smoothly. The ballast bed has a considerable influence on the service life and the quality of the track geometry and consequently the cost-efficiency of the overall track maintenance. When defined quality and safety standards are no longer met, operational measures such as speed restrictions, have to be implemented. If the poor condition of the ballast bed coincides with the sleepers and the rail requiring renewal due to wear, then a complete track renewal should be performed.

According to interviews two alternatives to the use of virgin ballast exist:

- the ballast can be cleaned on-site,
- the ballast can be transported to the waste treatment facilities.

More specific answers received from the interviewees are listed below.

DB: ballast can be recycled and returned to the existing track network (in 2020, 515,000 tons of ballast were, corresponding to a total of 16% of all installed ballast). Grains that cannot be reused are sorted out and sold to be recycled elsewhere, for example as aggregate in road construction. Grit is also processed in formation and frost protection layers.

NETWORK RAIL uses two techniques of ballast cleaning:

1. On-site ballast cleaning systems (Figure 6). Half-a-mile long, the BCS trains include locomotives at each end (to move the train to and from the work site in traffic up to 60mph); power cars to propel the train while in operation; 22 empty wagons for ballast waste; the ballast cleaner; the tamper/dynamic track stabiliser (DTS) machines (scroll to the end of this page to read more about DTS machines), and 22 wagons full of new ballast. This is a more environmentally friendly alternative to previous ballast cleaners.
2. Ballast treatment in the **Whitemoor** recycling centre. The ballast that comes to the treatment facility is usually cleaned, screened and then sold for use in road construction.

[35] Schmidt S, Shah S, Moaveni M, et al. Railway Ballast Permeability and Cleaning Considerations. Transportation Research Record. 2017;2607(1):24-32. doi:10.3141/2607-05

Figure 6: Network Rail ballast cleaner system (High Output machines)[36]

SNCF RESEAU pointed out the need to consider the issue of location of ballast. As there is no ballast quarry in the south-east of France, recycling is crucial. As a result, **SNCF RESEAU** decided to build a ballast recycling facility (Figure 7) in Miramas.

In 2020, a total of 30 000 tonnes were processed out of which approx. 60% was reinstalled in rail.

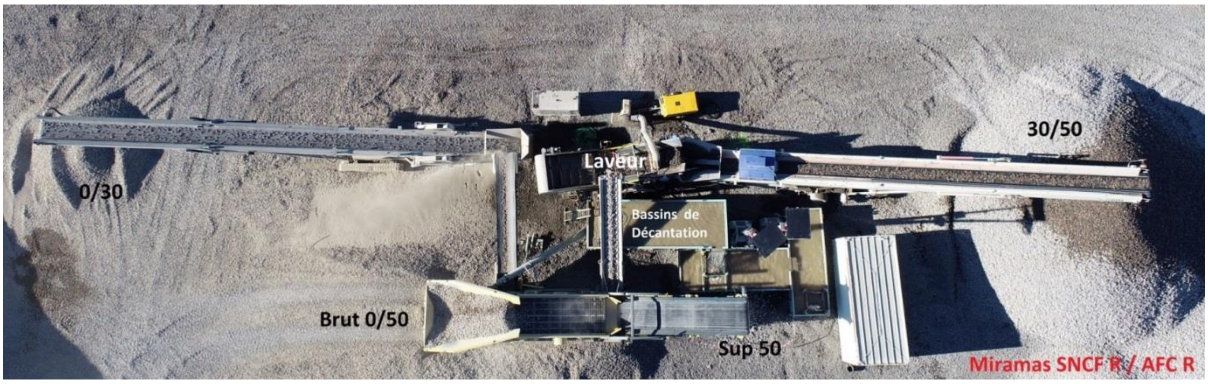


Figure 7: Miramas recycling facility

It is worth noting that all types of material that are being used in ballast beds are not suitable for cleaning using the current technological knowhow. For example, **Irish Rail** pointed out that the limestone they are using cannot be treated.

3.2.1. Sleepers

Railway sleepers, also called railroad ties, railway ties or crossties, are an important railway component. Generally, the rail sleeper is always lying between two rail tracks to keep the correct space of gauge. On the railroad construction, wooden rail sleeper, steel rail sleeper and concrete rail sleeper are the three most common types.

The best practices of handling sleepers after the end of the first round of use are summarized below.

[36] https://www.networkrail.co.uk/running-the-railway/looking-after-the-railway/our-fleet-machines-and-vehicles/high-output/high-output-machines/

DB pointed out an example of sleeper repairs. If cracks form in concrete sleepers, for example, they lose their stability properties and track position errors can occur. By repairing the cracks, and the bond restoration, the sleeper service lifespan can be significantly extended.

As part of the inspection process, dilapidated sleepers are reconditioned by DB Bahnbau and reinstalled in the DB track bed (in 2020, 240,000 reconditioned sleepers were installed corresponding to about 72,000 tons concrete, or 10% of all installed concrete sleepers).

NETWORK RAIL usually ships all used sleepers that are collected during the maintenance works to the centralized facilities where they are checked by the experts. If they meet the criteria for reuse, they are transferred back to construction sites. If the sleepers cannot be reused, they are being recycled, while the recycling technology depends on the sleeper material.

The concrete sleepers are usually crushed, the rebar is extracted and can be sold as scrap metal. The second component is the recycled aggregate, which can be used as a viable alternative for virgin aggregate in the production of new concrete.

The wooden sleepers are also being sold to be used for gardening and landscaping applications, furniture. It is worth noting special care needs to be taken with wooden sleepers as they can contain hazardous substances. In such cases the purchaser must have a waste carrier licence and environmental permit[37].

In addition to the typical recycling techniques, **SNCF RESEAU** pointed out the importance of keeping accurate material registers. Their CE task force identified an opportunity of reusing the material that is left over after the construction or renovation works. It is often the case that more material is ordered “just in case” then this material is left over at site.

TRAFIKVERKET has identified positive results from their “Design, Bid, Build” sleeper procurement process. A case study included a procurement covering 400,000 sleepers per year. A clause in the tender requested a 20% reduction of emissions over the period 2018-2022 whereby the tender did not explicitly state how the bidder should achieve the set goal (i.e., eco-friendly cements, recycled aggregates, shorter transport routes…) However, the tender clearly stated the requirement to use LCA methodology. Furthermore, Environmental Product Declarations (EPDs) are produced to verify climate performance. Preliminary results show a 26% reduction in CO_2 emissions and 14% cost reduction. Following this good practice, all new projects with a budget over 5 million EUR request an 18% reduction of CO_2 emissions compared to sleepers produced in a traditional manner. The final reduction is expected to be higher due to the possible financial bonuses.

3.2.1. Rails, switches, and fastenings

Rails, switches, and fasteners are mainly made of steel, a material that can be 100% endlessly recycled. Due to the high recyclability and relatively high value of scrap steel, this option often seems more attractive, as reusing components poses the following technical challenges when: lack of standardization of components, uncertainty of the efficiency of reused components, lack of knowledge of fatigue history and product composition, inappropriate decomposition handling. Despite the challenges, the authors were able to identify some best practices.

Most **interviews** confirmed that the steel components are checked by experts after the end of their first cycle of use. Next, a detailed inspection is being carried out with the following outcomes:

- if the components are “as good as new”, they can be reinstalled in all lines,
- if they are “almost as good as new” meaning that they meet the criteria for less frequent lines they are repurposed and used in less frequent lines (i.e., heritage line),
- if neither is possible the material is sold as scrap.

Alternatively, the worn-out rails can also be used as fence posts, supports for railway equipment such as signals, sold to produce designer furniture.

[37] https://www.legislation.gov.uk/uksi/2003/721/made?view=plain

SNCF RESEAU reported that 3,500 tonnes of removed rails were reprocessed by the electric steelworks of ASCOVAL (Saint-Saulve) to make 144 blooms (40% of old rails and 60% of scrap metals) Figure 8 illustrates SNCF RESEAU's project. The blooms were laminated and welded in long rail bars that have been laid on the tracks to be tested with a view to finalise the homologation.

Figure 8: Short loop: rail for rail project[38]

3.3. Rolling stock

Although reuse and recycling of rolling stock was not specifically addressed in the questionnaire, the interviewees exposed it as an important piece of the puzzle towards achieving the circularity goals. Besides best practices already mentioned in previous sections i.e., sustainable procurement, better quality of products, the interviewees pointed out a possible environmentally friendly approach consisting in dismantling and selling of whole or certain parts of ageing rolling stock that is no longer suitable for refurbishment.

Upcycled products made out of used materials have also been identified[39]: beach bags made from old train seat covers, table tennis and football tables made from train floors, design speakers of broadcast speakers; tables of train boarding steps and furniture of train floors, desks made of train ceiling panels, seats and chessboard table made of train floors and running boards, planters from trash cans, notepads, service sheets and lamps made of yellow travel information boards, bird nest boxes, feeders and decorative birds from yellow travel information boards, laptop covers and meditation cushion made of old train seat covers.

3.4. Other materials:

Railway companies are usually large organizations, so even small steps add up to non-negligeable environmental gains. The first material specifically highlighted by **IRISH RAIL**, and indirectly mentioned by all interviewees, is plastic. The challenge of limiting the use of disposable plastics was particularly highlighted. Among the good practices worth mentioning are the procurement request to deliver the cleaning products with returnable packaging, replacement of water dispensers with drinking water fountains, etc. Yet another very important way to reduce single use plastics is the abandoning tri-laminated tickets. Irish Rail reported an environmental saving of 5,319 kg CO_2e and a cost saving of € 70,000 annually without performance impact.

SNCF RESEAU has found out that specific plastics products made from polyamide 66, are becoming scarce therefore putting the market under pressure. Partnerships have been forged with the suppliers to develop recycling of used parts or to manufacture new parts with recycled material content.

SNCF RESEAU has also set up a recycling facility ("Recyclerie") in Beaune where all the small parts of railway equipment (hardware, plastics) can be sent, used or new, in order to be reviewed, inspected, reconditioned and repackaged, if need be, and then sold to an external industry or within the French railway to be used or re-used. In addition to plastics, the following assets where thoughtful procurement practice can lead to environmental savings, are also worth mentioning: IT equipment, clothing, office supplies...

[38] REUSE workshop presentation
[39] https://www.ns.nl/en/about-ns/sustainability/circular-enterprise/upcycled-products.html

4. Strategy for sustainable use of materials

This section sets out guidelines for the introduction of the CE in railway organizations. It is not possible to recommend a single, “one size fits all”, organizational template; however, some approaches have already proved to have a positive impact. A journey towards the CE includes ideas how to set the CE path, early ‘quick wins’ that can be implemented without major strategic and/or organizational changes and finally, the fundamental Key Performance Indicator (KPI) with which CE implementation can be measured. The findings presented below are based on a mixture of theoretical basepoints, stakeholder testimonies collected in interviews, and examples of best practice that have been identified during the discussion section of the REUSE workshop (section 5.3).

While stakeholders may value the CE concepts, they may not be ready to make the changes needed to achieve its full potential. To bridge this gap, possible actions, whereby the implementation sequence may vary based upon the individual organization background, are outlined below.

4.1. Strategic planning

For this transformational change, it is essential to embed the CE principles in the business strategy, values and organisational culture. The study has indicated the importance of the formal organization of the work process in taking advantage of the untapped potential that still exists. It is not only crucial that employees with appropriate knowledge in the railway industry operate in a bottom-up approach (based on the enthusiasm of individuals), but also a systematic and formal organization at company level has to be set up. Setting a clear policy and easily understandable objectives with visible leadership support will support change.

As railway infrastructure and their components have a long lifespan, their management requires a well-defined long-term sustainability strategy. When preparing the CE strategy, it is thoughtful to consider three well known sustainability pillars[40]:

- **Environmental sustainability**: the CE strategy can be considered as an add-on to a broader environmental sustainability strategic document. In general, the goals have to be aligned (i.e., preservation of natural resources, GHG reductions, energy efficiency) thus trying to reduce the amounts of virgin material extraction.
- **Economic sustainability**: Some recycling technologies are in the development phase and in some cases, costly, thus the resulting secondary raw materials (SRM) can be more expensive than primary material. With this in mind, it is important to perform a holistic technical and economic assessment to optimise the recycling process and receive the return on investment (ROI) in a manageable timeframe.
- **Social sustainability**: When implementing major organizational changes, it is important to strive towards general social consensus across the entire value chain. It is crucial that the strategy is built upon hard scientifically proven facts to improve acceptance of the CE.

Case Study

SNCF RESEAU (France)

SNCF RESEAU has established a task force of 10 people devoted to the CE strategy. Their aim is to come up with a strategy towards achieving the strategic goal to reuse or recycle 100 percent of main rail components by 2025 (rail, ballast, wooden and concrete sleepers and copper wires). Despite ambitious plans, they suggested adopting the so called “baby steps” approach, starting with carefully planned small-scale projects that can be scaled up.

[40] Rajeev, A.; Pati, R.K.; Padhi, S.S.; Govindan, K. Evolution of sustainability in supply chain management: A literature review. J. Clean. Prod. 2017, 162, 299e314.

Since 2018, the "Guichet Unique" has been centralizing all flows of used materials and has optimised the added value through re-using, recycling and energy recovering:

	2018	2019	2020
Revenue from recycling	45,5M€	36,7M€	25M€
Savings from reusing	NC	6M€	3M€

The results for the year 2020 for the main track materials are as follows:

	ReUsed	Recycled	Energy recovery
Rail	1000 t	42,9 kt →scrap 6 kt → new rail	-
Concrete sleepers	104 000 units	670 000 units	-
Wooden sleepers	Very few	-	51 kt (in a French plant - Novawood)
Ballast	230 kt	345kt	-

4.2. Promotion and capacity building

Technological innovation alone cannot drive the systemic changes needed to achieve a true transformation of the linear economic model. Viable changes presuppose a paradigm shift from individual behaviours to collective/cultural adoption of the CE principles. Thus, it is essential to establish promotion and staff education.

It is crucial to close the mindset gap between management and technical staff, to strive towards horizontal integration of departments and to promote both top-down as well as bottom-up awareness rising.

As a first step, identify already existing CE projects within the organizations. Despite not being specifically referred to as CE projects, some organizations have already well-established recycling, reuse, upcycling etc. practices that can be suitable for upscaling. The level of maturity in applying CE principles varies greatly from country to country and between business units within the same organisation. Just mapping the examples of good practice could lead to important leaps in terms of CE. A lot of materials that are already being reused or recycled should be systematically recorded.

A critical success factor is expert technical support to the business. A central expert unit that can focus on the topic can provide training, guidelines, and act as a centre of excellence for the business. Coordinating resource can connect experts throughout a large and complex organisation, offer support and advice. Central and strategic expertise will also help to reinforce a strategic approach as given in section 4.1.

4.3. Cross-sector collaboration

It is clear that to switch to an entirely circular economy model, no company or sector can work alone. Some of the most innovative opportunities for reusing materials come through linking into entirely different types of companies. Indeed, the model of public private partnerships and models of deeply collaborative partnerships between large multi-nationals and small local businesses can be very fruitful for all partners. The railway industry must work together to break down barriers to material re-use, cross borders between operator and infrastructure managers, tenants and landlords, clients and supply chain and with other sectors and industries. Other sectors that the rail industry might target include agriculture and large local landholders, aggregates and road building organisations, heritage rail or museums, local business, community groups and schools, other large building construction projects, conservation or flood protection bodies, or metal working/smelting industries.

One example of working with a different organisation is the success story is the Wallasea Island Wild Coast Project in Essex, United Kingdom. This was a partnership between a rail project (Crossrail)[41], the construction sector and the charity The Royal Society for the Protection of Birds (RSBP). The Wallasea Island collaboration provided several benefits as the result of Europe's largest construction project. Only 80 miles away, the Crossrail project will, when complete, transport an estimated 200 million people each year and eliminate up to 30,000 car trips in and out of London daily. Among Crossrail's sustainability goals is a 95% reuse or recycle target for the earth excavated from the massive tunnelling project. More than 4.5m tonnes of that earth will end up in Wallasea Island - largely transported there via rail and road, further reducing Crossrail's carbon emissions associated with the movement of waste. This waste aggregate will restore coastal marshlands and help protect land from rising sea levels.

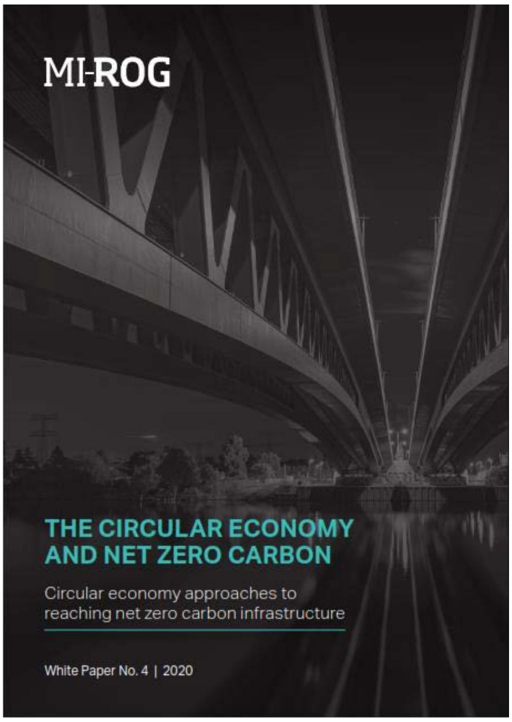
Case Study

MI-ROG & SICEF (United Kingdom)

MI-ROG & SICEF (the Major Infrastructure - Resource Optimisation Group and the Scottish Infrastructure Circular Economy Forum) are forums convened by AECOM for the UK's infrastructure operators to collaborate across the circular economy theme and to meet the challenge of delivering major infrastructure in a constrained economy. These forums have been in existence since 2013 & 2017 (SICEF).

MI-ROG has inspired and facilitated workflows on asset life cycle, carbon performance, circular economy planning, critical materials availability, materials exchange mechanisms and sustainable procurement and supply chains including several published White Papers. The group benchmarks approaches, shares best practice and collaborates across projects, seeking greater resilience and efficiencies with planning, development, and delivery of major programmes. MI-ROG's and SIECF's joint mission is to be a facility for fully circular infrastructure delivery by 2030.

https://aecom.com/projects/circular-economy-action-major-infrastructure-resources-optimisation-group-mi-rog/



The cross-industry collaboration NISP takes a similar approach using the principles of industrial symbiosis. Through the network, NISP identifies mutually profitable transactions between companies so that underused or undervalued resources (including energy, waste, water and logistics) are brought into productive use.

http://www.nispnetwork.com/

4.4. Sustainable Design

The research shows the importance of the design[42] phase in the product life cycle and the importance of well-defined methodology based on which the proposed design solutions can be compared.

[41] https://www.crossrail.co.uk/benefits/environmental-sustainability/

[42] In the context of this report the "design" is not referred to only as aesthetic geometrical property of certain product, it denotes the functional qualities established from creative, rational, and iterative innovation process to create solutions with reduced whole life cycle cost.

Case Study

TRAFIKVERKET (Sweden)

TRAFIKVERKET apply the "Design, Bid, and Build" approach where contractors are responsible for detailed planning. In this approach, the technical description specifies what should be done and priced according to the bill of quantities. The technical descriptions of the functional requirements have to be accurately specified by the investor also in terms of lower virgin material consumption, while the contractor may decide on production methods, materials, etc. within certain limits. TRAFIKVERKET use the Klimatkalkyl methodology to calculate the LCA result.

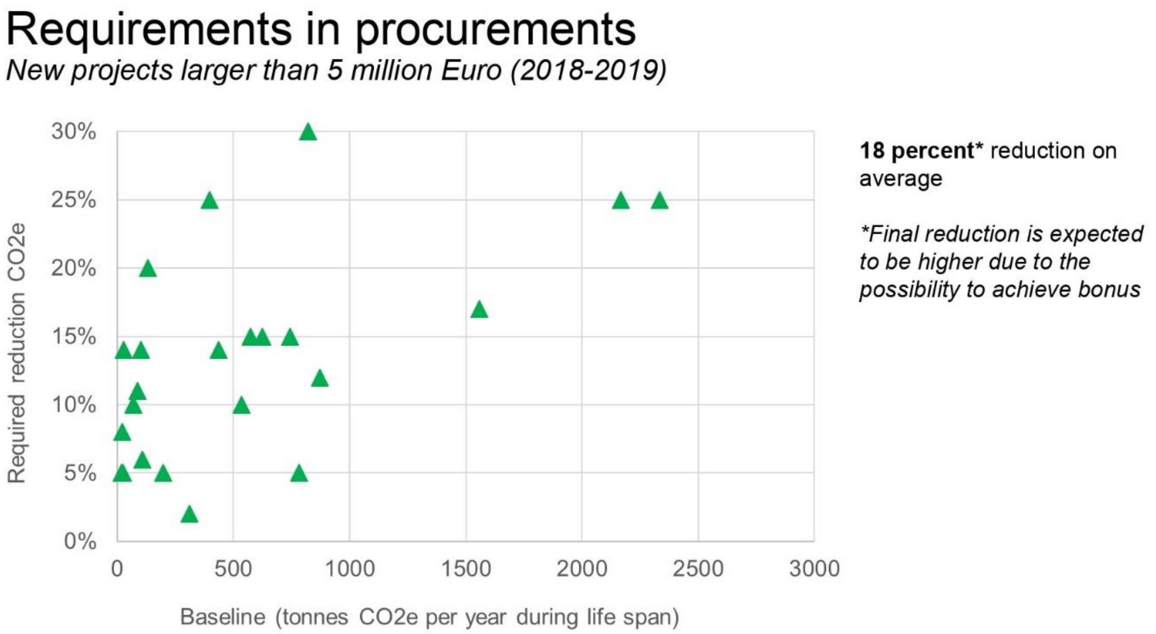


Figure 9: CO2 reductions achieved by TRAFIKVERKET[43]

4.5. Sustainable Procurement processes

Green procurement is an important driver when trying to adopt the CE. Procurement is indeed no longer the sole responsibility of the procurement officer, but it has become a process related to, and possibly even owned by, several different departments. Successful circular procurement requires collaboration between different departments and roles. In circular procurement, it is preferable to establish a long-term relationship between the buyer and the supplier. A collaborative and long-term relationship is important as it encourages circular use, which is a shared responsibility of the buyer and the supplier.

Another important best practice that was pointed out in several interviews is the practice of **renting instead of buying**. The idea behind this model is to provide a means to incentivise the suppliers to provide products with higher lifespan.

[43] REUSE workshop presentation

Case Study

PRORAIL

PRORAIL, the Dutch Infrastructure manager,has found a way to justify higher costs versus lower environmental impacts through making a monetary valuation of the environmental impact in the bid evaluation.

The Environmental Cost Indicator (ECI) is a helpful tool to achieve this. This indicator is used in a tool (DuboCalc) to calculate the environmental costs of project. And these costs are a factor in the tendering process. A proposal with lower ECI has a substantial advantage. The tool was first used by the Dutch highway authority administration, but it has since then been adopted by the railway operators.

To calculate the individual ECI, the following LCA steps need to be followed (Figure 4).

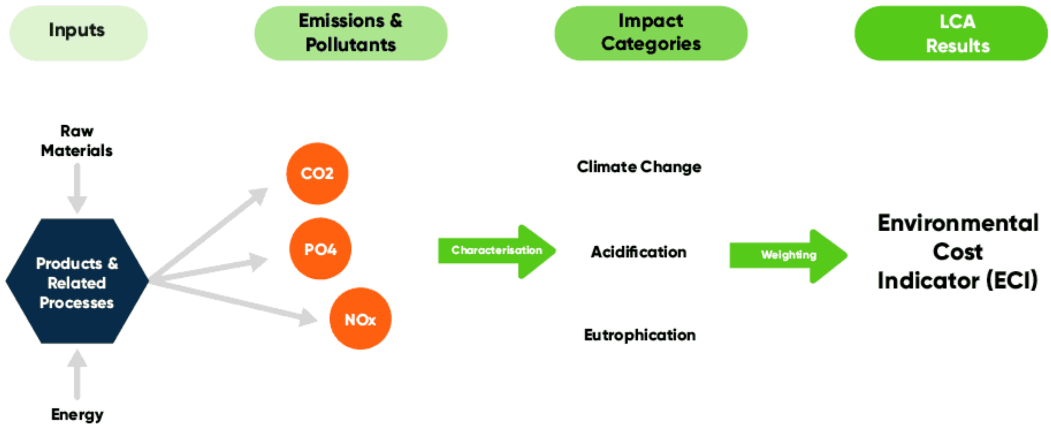


Figure 10: Environmental Cost Indicator (ECI) Calculation

The ECI is a single-score indicator expressed in Euro. It gathers all relevant environmental impacts into a single score of environmental costs, representing the environmental shadow price of a product or project. To calculate the price reduction ECI takes into equation estimated reference environmental impact (ECI ref), offered environmental impact (ECI offer), predefined targeted environmental impact (ECI target) and predefined maximum advantage.

$$price\ reduction\ = \frac{(ECI\ ref - ECI\ offer)}{(ECI\ ref - ECI\ target)} * maximum\ advantage$$

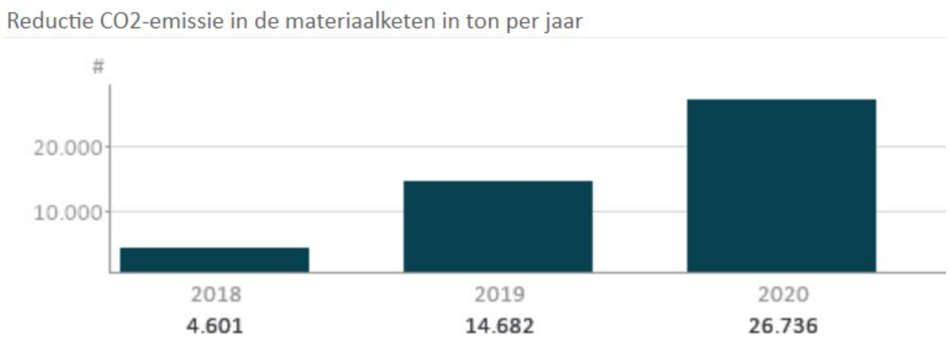


Figure 11: Indication of the achieved reduced CO2 emissions in the material chain, based on the purchasing process using ECI (tonne/annum).

In procurement, the specification and bid evaluation process is a good opportunity to set a clear message to the supply chain on the objectives of the contract regarding circularity. Bidders can be asked to demonstrate how they will manage materials and wastes using CE principles. Bids can be evaluated to consider the whole life impacts of the products or service they are proposing.

4.6. Digitalisation

Digitalisation is one of the main CE enabling factors. Information technology (IT) can increase the visibility, smartness, location, condition, and availability of assets. The idea behind digitalization is to establish centralised systems that can:

- track the journey of assets,
- record the assets material composition,
- keep track of asset ownership,
- monitor the condition of assets.

Such IT systems could:

- facilitate the "product-as-a-service" approach (*i.e., the steel installed in railways could be owned by steel manufacturers*[44]);
- prolong the asset lifetime (*i.e., predictive databased maintenance could result in lower operational costs*);
- increase the value of depreciated assets (*i.e., asset registers can also serve as data source for online auction sites as it is often the case that old assets are left in the warehouse or sold for a low, almost nominal price*).

Case Study

Network Rail (United Kingdom)

The SURPLUS app is an internal circular economy app which allows users to find assets which are no longer required in one area of the business and re-use it in another area of the business. Users can sell unwanted items to other Network Rail sites allowing them to be reused rather than sent to landfill. Since launching in January 2019, over 470 employees have trialled the app[45].

This creates cost efficiency for Network Rail and removes the requirement for new, excess assets to be sent to landfill.

4.7. Research and innovation

Turning the materials and products that have reached the end of their life into new resources is a major segment of CE. To make it happen, research and innovation is needed to demonstrate the economic and environmental feasibility.

- **SRM-based construction products**: Development and testing of new/alternative materials for rail components is an important step towards reducing the extraction and consumption of materials from primary sources. When developing new materials, however, care must be taken that the inventions really contribute to long-term environmental sustainability. For example, it is necessary to prove that alternative materials have the same technical properties also on the long run.
- **Novel business models**: As implementation of CE may require investments and because benefits sometimes are not easily quantifiable, research is needed to come up with sustainable CE business models. A broad audience need to be considered as CE can have indirect multiplier effects that conventional economic analyses do not show (i.e., new markets, better corporate identity, fresh capital, and risk mitigation).

[44] https://ec.europa.eu/programmes/horizon2020/sites/default/files/ce_booklet.pdf
https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Intelligent_Assets_Case_Studies_1002016.pdf
[45] https://www.networkrail.co.uk/wp-content/uploads/2019/07/Annual-report-and-accounts-2019-Being-responsible.pdf

Case Study

Sleepers from alternative recycled materials

Made from recycled plastic, engineers recently installed the environmentally friendly technology across the weight-restricted Sherrington Viaduct, between Salisbury and Warminster, in the United Kingdom. Previously, track across the viaduct would have had to be fitted with wooden sleepers, as concrete would have been too heavy for the structure. Sleepers sit on the ballast and hold up the rails, keeping them the correct distance apart.

The recycled composite sleepers will help Network Rail achieve its Zero Carbon 2050 target due to at least a 40% reduction in greenhouse gas emissions from sleeper production and embodying recycled plastic within the track infrastructure for at least 50 years.

The sleepers also offer an increase in service life and reduced maintenance compared with timber sleepers, helping to reduce both whole life costs and the risks to staff when attending site.

Unlike traditional wooden sleepers, composite sleepers do not split, rot or degrade over time and can resist water, oil, chemicals and fungi. Designed for over 50 years of use, when they are eventually replaced, they can be re-used, re-purposed or recycled to make new sleepers or other composite products.

Figure 14: Beyond wood - first recycled plastic railway sleepers laid on Network Rail tracks[46]

4.8. Quick wins

Our research has shown that quick wins primarily coincide with the first set of “9R strategy” (refuse and rethink). Individual best practice examples are presented in Section 3, but from the overall perspective, we can point out that clear guidelines and conditions need to be set in the procurement process.

- **Prioritise**
  Focus on your biggest waste volumes or largest costing raw materials first. Perhaps also consider the most visible products for your customers to generate positive perception and press in stations or onboard trains.

- **Rent instead of buy**
  This approach can be considered to motivate bidders to deliver products with a longer lifespan.

[46] https://www.networkrail.co.uk/news/beyond-wood-first-recycled-plastic-railway-sleepers-laid-on-network-rail-tracks/

- **Easy swaps**
  Are there alternative products that can be replaced with higher recycled content that perform as well and are cost neutral? Ask suppliers for their alternative products.

- **Networks of champions**
  Rail organisations can be geographically spread and complexly organised. To spread good practice and find solutions that suit each business unit, engage a network of local CE champions. Each champion can raise awareness in their local teams, focus on local steps that can be taken in their facilities and processes and can share knowledge as a network throughout the business.

- **Pilot projects**
  Introduce small projects to demonstrate value and then scale them up. This is an efficient way to push the CE practices into practical use.

4.9. Key performance indicators

By definition, a KPI is a quantifiable measure used to evaluate the success of an organization, employee, asset, etc. in meeting objectives for performance[47]. The operative word in KPI is “key” because every KPI should relate to a specific outcome with a performance measure.

When preparing a KPI matrix, it is important to define clear measurements of how to obtain input data and how to qualify the results. Furthermore, it is important to tailor made the KPIs and associated goals according to the initial situation in individual organization as blind copying of the KPIs from one organization to another without a clear implementation strategy can be counterproductive.

We can distinguish the general strategic and the operational KPIs. The strategic KPIs are used to monitoring progress or trends toward a stated destination on a long run, and the exposure to technological trends should be avoided. On the other hand, the operational KPIs seek to measure the progress in real time in order to assess what is happening on the field.

Commonly used strategic KPIs

When designing strategic indicators for organizations, it makes sense to follow the goals defined in industry, national or European strategic documents. For example, the EU Monitoring Framework for the CE presented by the EC in 2018. The framework outlines 10 key indicators covering each phase of the lifecycle of products as well as competitiveness aspects.

[47] Oxford dictionary

Table 2: Circular economy strategic indicators[48]

	Indicator	Definition
Production and consumption	EU self-sufficiency for raw materials (percentage EU against outside)	The indicator measures how much the EU is independent from the rest of the world for several raw materials. The indicator is expressed in % and is defined as: 1-(net) Import reliance.
	Green public procurement	The indicator measures the share of public procurement procedures above the EU thresholds (in number and value), which include environmental elements.
	Generation of municipal waste per capita	The indicator measures the waste collected by or on behalf of municipal authorities and disposed of through the waste management system. It consists to a large extent of waste generated by households, though similar wastes from sources such as commerce, offices and public institutions may be included.
	Food waste	The indicator measures the waste generated in the production, distribution and consumption of food (in mass unit).
Waste management	Recycling rate of municipal waste	The indicator measures the share of recycled municipal waste in the total municipal waste generation. Recycling includes material recycling, composting and anaerobic digestion. The ratio is expressed in percent (%) as both terms are measured in the same unit, namely tonnes.
	Recycling rate of overall packaging	The indicator is defined as the share of recycled packaging waste in all generated packaging waste. Packaging waste covers wasted material that was used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer, excluding production residues. The ratio is expressed in percent (%) as both terms are measured in the same unit, namely tonnes.
SRM	Contribution of recycled materials to raw materials demand	The contribution of recycled materials to the raw materials demand is represented by two indicators. a. End-of- life recycling input rate (EOL-RIR) measures for a given raw material how much of its input into the production system comes from recycling of "old scrap". b. The circular material use rate (CMU rate) is defined as the ratio of the circular use of materials (U) to the overall material use (M) (M = DMC + U).
	Trade in recyclable raw materials	The indicator measures the quantities of selected waste categories and by-products that are shipped between the EU Members States (intra-EU) and across the EU borders (extra-EU). Five classes have been selected: plastic; paper and cardboard; precious metal; iron and steel; copper, aluminium and nickel. The indicator includes the following variables: ▪ Intra EU trade of selected recyclable raw materials (measured as the Imports from EU countries). ▪ Imports from non-EU countries and exports to non-EU countries of selected recyclable raw materials (as regards extra-EU trade). The indicator is based on International Trade in Goods Statistics (ITGS) published by Eurostat. The scope of the "recyclable raw materials" is measured in terms of relevant product codes from the Combined Nomenclature used in International Trade in Goods Statistics (see list of codes selected).
Competitiveness and innovation	Private investment, jobs and gross value added related to circular economy sectors	The indicator includes "Gross investment in tangible goods", "Number of persons employed" and "Value added at factor costs" in the following two sectors: the recycling sector and repair and reuse sector. The recycling and repair and reuse sectors are defined and approximated in terms of economic activity branches of the NACE Rev. 2 classification. The following NACE codes have been selected to compute this indicator: (see list of codes selected). The indicator is collected within the frame of the Structural Business Statistics (SBS), as required in Commission Regulation N° 250/2009.
	Number of patents related to recycling and secondary raw materials	The indicator measures the number of patents related to recycling and secondary raw materials. The attribution to recycling and secondary raw materials was done using the relevant codes in the Cooperative Patent Classification (CPC). (List of CPC codes selected) The term 'patents' refers to patent families, which include all documents relevant to a distinct invention (e.g., applications to multiple authorities), thus preventing multiple counting. A fraction of the family is allocated to each applicant and relevant technology.

[48] https://ec.europa.eu/eurostat/cache/scoreboards/CE_DataBro/index.html#

Commonly used operational KPI

Under the term operational KPI, we understand a measurable value that expresses business performance in a shorter time frame. The purpose of defining and evaluating KPIs is mainly to track organizational processes, and individual projects to improve efficiency and help to optimize strategies. The presented list of operational KPIs (Table 3), is based on the input obtained in the REUSE interviews and at the REUSE workshop.

Table 3: Circular economy strategic indicators

	Indicator	Description
Design	Usage of standardized modular and interchangeable materials and systems	The indicator measures the share of modules, parts or materials that can be replaced with similar generic spare entities.
	Availability of as-built drawings, labelling of connections and register of installed material	The indicator measures the amount of detail about the products and or assets. If possible, the details should be digitally stored (i.e., Building Information Models).
	Virgin vs. recycled material used in products	The indicator measures the share of recycled material used in production.
	Repairability rate	The indicator measures the share of not working modules, parts or materials which can be replaced to recommission the product.
Assets and product procurement	Total cost of ownership	The indicator indicates the total expenses including the purchase price, maintenance and post-life treatment costs including.
	Lifespan extension	The indicator measures the predicted lifespan extension compared to conventional products.
	Environmental footprint	The indicator measures the overall environmental burden including the virgin material extraction, material processing, and treatment after the end of life.
Valorisation of used products	Revenue from recycling	The indicator measures the revenue arising from the reuse of or the revenue from the selling of unneeded materials.
	Money saving from reusing	The indicator measures the overall cost reduction arising from the reutilization of used products.
	Recyclability rating	The indicator measures the amount of material that can be recovered after the end of lifespan.

To measure, evaluate and compare the CE, various tools have also already been established by the EC.[49]

[49] https://ec.europa.eu/environment/green-growth/tools-instruments/index_en.htm

Case Study

Deutsche Bahn (DE)

DB strives to be a full circularity-oriented company over the whole supply chain. Since 2015, they are pursuing a group-wide recycling rate of 95% across all DB waste fractions by 2020.

To achieve this vision, the following measures are in development:

1. Substituting concrete with sustainable concrete options like RC-concrete or CO2 neutral concrete, e.g., in platforms and stations.
2. Excluding single use plastic items and packaging.
3. Increasing the percentage of reuse concrete sleepers and ballast.
4. Defining sustainable tendering criteria, e.g., Design-to-Recycling and Design-for-Environment.

https://gruen.deutschebahn.com/en/strategy/resource_protection

5. Conclusion

This report has outlined the results and observations made during the implementation of the UIC REUSE project. It can be concluded that stakeholders across the entire value chain of the railway sector are aware of the importance to reduce the exploitation and dependency of virgin raw materials in order to achieve the sustainable development goals.

Moreover, it is not just about awareness, as this work has identified examples of well-established CE best practices in railway related organizations.

Equally important, it can be concluded that early adopters have already managed to display CE case studies showing positive environmental and financial impacts. Accordingly, this document is intended to motivate and guide railway organizations that are just beginning to join CE.

The “where to start guide” outlined in the last section of the report can be taken as a reference point for the preparation of short, medium and long-term CE strategies. However, it is essential to emphasize that implementation of the CE is something that cannot be implemented in the sense of “one strategy fits all”, as it has been well identified that despite stakeholders are pursuing similar goals their implementation strategy may vary significantly.

Annexes

5.1. Annex 1: Questions asked in the first survey

- Are materials reused in your company?
- IF NO, why is reuse not yet considered by your company?
- IF NO, would you consider reuse of materials in the future? Which conditions/criteria are important for you? Which materials?
- IF YES, from which perspective is reuse important for your company?
- Reuse policy
- Does your company have a policy on reusing materials?
- What is the timeframe of your company's reuse policy?
- Do you follow up key performance indicators (KPIs)? Please list the KPIs you are following up and explain.
- Do you apply life cycle analysis (LCA)?
- Do you consider Eco-design in your processes? How?
- Which tools do you use?
- Which processes are linked to reuse of material in your company?
- Which materials are reused in your company? For which applications?
- Which department within your company is doing the coordination of material reuse?
- Would you be interested in participating in events to share experiences?
- Which topics would you like to be addressed?

5.2. Annex 2: Questions asked in the second survey

General questions

- What is the core business of your organization?
- What is the size of your organization?
- Does your organization have a department dedicated to sustainable development?
- Does your organisation have any resource (staff) with expertise dedicated to Circular economy?

Organization and CE

- To what extent is the CE and more generally sustainable development important for your organization? (Rate 1-5)
- Does your organization have a circular economy transition strategy in place?
    - If yes,
        - please list main goals, KPIs, and the time frames

- If not, what do you think is the reason?
  - The organization leaders are not familiar with the benefits of CE.
  - Now, it is not the right time to establish such a strategy.
  - We are already establishing the strategy with internal resources, and we are confident that we have enough knowledge, to prepare the strategy.
  - We are trying, or have already tried to establish a strategy, but we would need external help.
  - We find such a strategy irrelevant. (Please elaborate)

Please classify the priorities you follow when planning construction, maintenance and renovation projects on railway infrastructure.

- Price,
- Durability or performance quality,
- Environmental or social impact during the project construction stage,
- Long term environmental or social impact (operation and end of life).

Do you perform simulations of environmental impacts when preparing projects, i.e., EIA, LCA, LCC, S LCA?

Can you point out innovative technologies or practices that embed sustainability principles during design stages?

Materials

Please list the materials that in your opinion bear the most potential to be reused.

- If you are already reusing materials, which ones and to what extent?
- In addition to environmental impact, does the material reuse impact financial view of project?
- Please list the financial benefits and burdens associated with reuse of materials?
- Was it necessary to adjust the project planning and monitoring process?

Please list materials that bear the most potential to be recycled.

- Which reusing/recycling process and related materials do you estimate as to the best sustainable practice in your organization?
- Do you see that cross-country collaboration in terms of material exchange could be beneficial, if yes and why?
- Is your organization engaged in any sort of cross-sector partnership or industrial symbiosis to manage material flow?

Concluding part

- Are you familiar with the mechanisms for promoting the transition to a circular economy? (EU funds, national and regional development programs, other subsidies)?
- Is your organization involved in projects and or consortia as a part of these mechanisms?
  - If yes, please list them.
  - If not, why?

- Do you think that current standards and legislation sufficiently encourage the transition to a circular economy?
- In your opinion, how can your organization directly benefit from the transition to a circular economy?

5.3. Annex 3: REUSE workshop

The interactive workshop on sustainable use of resources, reuse, and circular economy in railways (REUSE) was held on-line on 15 April 2021. The goal of the workshop was to present communicate best practices on CE in railway sector, present preliminary findings of the REUSE project, and to Kick Off for the new UIC Circular Economy Sector.

Agenda

Topic	Presenter
Welcome and Keynote speech	I. De Keyzer (UIC), Chr. Vanoppen (LINEAS, BE), Chair of UIC Sustainability Platform
Background of the REUSE project. Announcement of launch of the CE Sector under UIC Sustainability Platform (call for interest/ call for chair/first sector meeting date)	Isabelle De Keyzer (UIC)
From circular policies to practices in railways management	Alenka Mauko (ZAG)
Environmental cost indicator. A tool in design and procurement.	Ted Luiten (ProRail)
CE in design and procurement - LCA based climate requirements at the Swedish Transport Administration	Susanna Toller (Trafikverket)
Network Rail: Whitemoor Aggregate Handling Depot - for reuse and recycling of material	Katy Beardsworth (Network Rail)
Circular economy - strategy and achievements	Benoit Aliadière (SNCF Réseau)
Circular Economy Initiatives Train Operation & Maintenance	Heidi Hopper-Duffy (Irish Rail)
Presentation of the report main findings and aim of the break-out rooms	Sebastjan Meža (ZAG)
Break-out room session	Individual room hosts
Wrap up and closing words	I. De Keyzer L. Anderton

The workshop was moderated by Isabelle De Keyzer (UIC).

Discussion

Large amounts of time in workshop agenda were devoted to moderated discussions in the break-out rooms. All workshop participants were automatically assigned to break-out rooms based on their previously expressed interest.

	Subject	Moderator
Room 1	Legislation and national targets	Alenka Mauko Pranjić (ZAG)
Room 2	Circular design	Stanislav Lenart (ZAG)
Room 3	Strategies and KPIs	Sebastjan Meža (ZAG)
Room 4	Procurement and working with our Supply chain	Ted Luiten (ProRail)
Room 5	General best practices in other material reuse	Heidi Hopper-Duffy (Irish Rail)
Room 6	Partnerships with other sectors	Lucie Anderton (UIC)

INTERNATIONAL UNION OF RAILWAYS
16, rue Jean Rey - 75015 Paris - France
Tel. +33 (0)1 44 49 20 20
Fax +33 (0)1 44 49 20 29
E-mail: info@uic.org

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