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The Role of Environmental Product Declarations in Decarbonizing Railway Infrastructure

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Abstract

This paper presents a systematic analysis of Environmental Product Declarations relevant to railway infrastructure with the objective of evaluating their suitability for supporting decarbonisation-oriented decision-making. A structured assessment of 89 declarations identified via the ECO Platform was conducted, examining product category coverage, programme operator representation, declaration type, geographical representativeness, applied product category rules, background databases, and declared life cycle modules. The results show that EPD availability is uneven across railway infrastructure components and strongly concentrated in concrete-based products, while several key components remain underrepresented. Significant methodological heterogeneity was observed, including variation in declaration types, applied PCRs, life cycle coverage, and background database versions, which limits comparability and constrains system-level application. Generic construction product PCRs dominate, whereas railway-specific PCRs are rarely applied, reducing the relevance of EPDs for infrastructure-specific decarbonisation strategies. Overall, the analysis demonstrates that current EPD practices primarily enable material-level transparency rather than comprehensive infrastructure-level carbon assessment. The findings highlight the need for expanded EPD coverage, greater adoption of railway-specific PCRs, and improved methodological harmonisation to strengthen the role of EPDs in railway infrastructure decarbonisation.

Keywords: railway infrastructure, decarbonisation, life cycle assessment, environmental product declarations, product category rules, embodied carbon

1 Introduction

The issue of greenhouse gas (GHG) emissions from transportation systems has become a subject of increasing public and political concern. Although rail transport is generally regarded as a sustainable alternative to road and air transport with regard to operational emissions, the associated infrastructure can contribute significantly to a project's overall carbon footprint [1, 2] and should be considered in decarbonisation strategies in the railway sector [3].

Driven by the EU's Green Public Procurement initiative, which encourages the procurement of environmentally friendly products in the public sector [4], the incorporation of Environmental Product Declarations (EPDs) into the procurement criteria has the potential to contribute significantly to the decarbonization of construction materials. An EPD is a standardised document in which transparent, objective, and third-party verified information about the environmental impacts of a specific product are presented for business-to-business communication [5]. By increasing data transparency, enabling comparisons, and integrating product impacts into construction decisions, EPDs can play an important role in infrastructure decarbonisation [6, 7].

However, the effectiveness of EPDs as a decarbonisation instrument depends on the availability, quality, and consistency of EPD data**.** Compared to the building sector, railway infrastructure has received limited attention with respect to EPD development and application, potentially constraining the use of EPDs for carbon reduction at a system level. Therefore, this study aims to assess the current availability and characteristics of EPDs for railway infrastructure components, and to discuss their implications for infrastructure decarbonisation. By focusing on methodological aspects rather than product emissions, this study seeks to clarify the possible role of EPDs in the decarbonisation of the railway infrastructure sector.

1.1 Regulatory Framework for EPDs

EPDs are grounded in ISO 14025 and provide independently verified and quantified environmental impacts of products across their life cycle. They are based on quantitative life cycle assessment (LCA) results, carried out in accordance with ISO 14040 and 14044 standards [8, 9]. The methodological choices and requirements for the development of an EPD for a given product group are defined in so-called Product Category Rules (PCRs) [5]. PCRs aim to ensure comparability of results in the same product category and to provide a standardized, and transparent basis for accurately quantifying and communicating environmental attributes [10, 11].

For construction products and services in buildings and civil engineering works, ISO 21930 complements the general standards by providing core rules for this product category. On the European level, EN 15804 serves as a core PCR for construction products to harmonise the EPD development, defining, e.g. ,the calculation rules for the LCA, the requirements of data quality, and the presentation of results [12].

EN 15804 divides the life cycle of construction products into distinct phases: product stage (modules A1 to A3), construction process stage (A4 to A5), use stage (B1 to B7), end of life stage (C1 to C4), and benefits and loads beyond the system boundaries (module D) [12]. The life cycle phases and included modules are presented in Figure 1. The updated version EN15804+A2 makes the inclusion of modules A1-A3, C1-C4 and D mandatory for all EPDs for construction products.

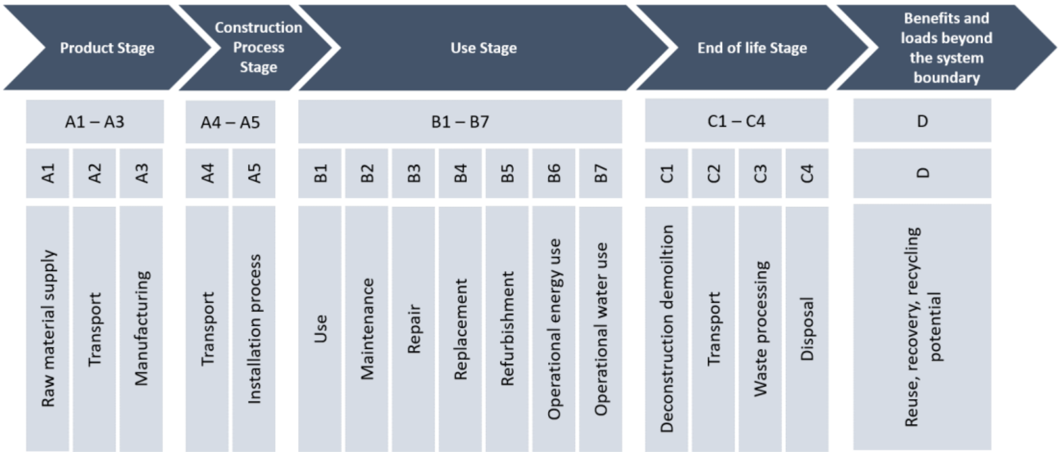

Figure 1: Lifecycle phases for EPD creation according to EN 15804 (own illustration based on EN 15804+A2)

1.2 Development and use of EPDs

Although the use of EPDs is of a voluntary nature [5], the demand has strongly increased in recent years. The literature indicates an exponential growth in EPDs since their establishment [13], with the construction sector dominating published declarations [14, 15]. This development is mainly driven by the reliance of building certification schemes like LEED, BREEAM and DGNB on EPDs [16, 17] and green public procurement [15].

Although EPDs are commonly used by practitioners for product comparison [18], comparability is frequently limited. Programme operators (POs), managing PCR development, and verification and registration of EPDs, have emerged independently, resulting in limited coordination [19], inconsistent product categories [11], shortcomings in verification [20], and heterogeneous implementation of standards and guidelines [21, 22]. The uncoordinated creation of PCRs leads to overlapping and sometimes competing PCRs, undermining the consistency required for comparable EPDs [23]. A key barrier to harmonisation lies in the definition of product categories, which is handled differently across POs [11, 19]. Additional challenges include the lack of shared data sources, geographical applicability [11], and differences in scope, system boundaries, impact categories, and allocation procedures [19]. These methodological inconsistencies directly affect the validity of EPD-based comparisons. Studies have shown that only a minority of potential EPD comparisons are valid, even when declarations claim compliance with the same PCR [24, 25]. Missing or inconsistent application of key PCR elements [25], differing system boundaries [26], and variation in background data [27] and modelling parameters [28], have been identified as major sources of inconsistency.

At the organisational level, harmonisation efforts resulted in mutual recognition agreements between POs [10, 13, 22, 25] and the establishment of the ECO Platform as an international umbrella organisation for POs pursuing global harmonisation [29]. Nevertheless, the literature stresses that substantial work remains before harmonisation and comparability are achieved at a level that fully supports reliable environmental decision-making.

1.3 Use and transferability of EPDs to railway infrastructure

Previous studies have examined the transferability of environmental assessment methods from the building sector to civil engineering structures, including railway infrastructure. Factors that limit direct transfer include differing system boundaries, longer service lives, larger affected areas, distinct technical and functional requirements, construction phase impacts, and increased complexity in applying Module D [30]. Furthermore, building assessments are frequently driven by market value considerations, which are not directly applicable to infrastructure assets [30]. Saxe et al. [31] argue that the large scale and uniqueness of railway infrastructure projects complicate the consistent application of conventional assessment methods at the system level, and that ISO 14040/14044 may not fully capture infrastructure-specific characteristics. In addition, transport infrastructure impacts can extend beyond the immediate life cycle, with interdependencies between components further complicating assessment [32].

Early work on railway-specific EPDs was presented in 2010 in form of a whole-system assessment of the Bothnia Line in Sweden, resulting in eight EPDs covering infrastructure elements as well as transport services [33]. This work was supported by railway-specific PCRs published under the International EPD System. Currently, a c-PCR for railway infrastructure effect, which exceeds the requirements of the corresponding PCR2019:14 by requiring full life cycle coverage (modules A–D) and explicit consideration of land-use-related emissions [34]. Despite railway infrastructure remaining largely absent from EPD literature, a study [35] indicates that EPDs and material passports are the most used environmental labels in the railway sector, motivating the analysis presented in this study.

2 Methods

To evaluate the role of EPDs in decarbonising railway infrastructure an analysis of the availability and quality of existing EPDs for railway infrastructure was conducted. EPDs were collected between December 2025 and January 2026 from the ECO Platform, which, at the time of data collection, included over 30,000 EPDs from 20 different POs [36].

EPDs were included if they were valid at the time of data collection and clearly applicable to railway infrastructure components, or materials commonly used therein. Declarations related to rolling stock or railway operations were excluded. To enable consistent comparison, railway infrastructure was divided into the following component categories: rails; sleepers; track bed (including ballast, mats, and base plates); structural concrete and concrete elements; rail fixation systems; noise protection; turnouts; and other components related to railway infrastructure.

The ECO Platform database was searched using category-specific search terms. For each term, relevant and valid entries were screened manually to ensure applicability to railway infrastructure. EPDs were excluded if they had already been identified under previous search terms, were not relevant to railway infrastructure, or did not provide usable data. This process resulted in a final dataset of 89 railway-relevant EPDs. As the analysis is based on a single platform, it does not capture all EPDs available globally, despite covering multiple POs.

Each included EPD was subsequently reviewed with respect to POs, EPD type, geographical representativeness, applied standards, background database, product category, applied PCRs, and declared life cycle modules. Data were extracted from both the ECO Platform metadata and the EPD documents themselves, enabling a structured comparison of EPD availability, methodological consistency, and usability for decarbonisation-oriented decision-making.

3 Results

The following subsection presents the results of the EPD analysis, focusing on availability, methodological attributes, and scope.

3.1 General EPD availability

The assessment of the ECO Platform database identified a total of 89 EPDs related to railway infrastructure, indicating that EPD development in this sector has progressed beyond isolated pilot applications. However, when compared with the exponential growth of construction product EPDs [13, 37], railway infrastructure remains clearly underrepresented.

The reviewed EPDs were published by nine different POs, with the International EPD System accounting for over 60 % of the total, indicating its dominant role in this sector. The next most represented POs were EPD Norway and the German Institut Bauen und Umwelt e.V., with eight and seven EPDs respectively, This distribution reflects the overall pattern of dataset availability across POs on the ECO Platform [36]. Figure 2 presents an overview of POs and their respective numbers of published EPDs.

The identified EPDs originate from 34 different EPD owners, which highlights a relatively broad participation of manufacturers within the railway infrastructure sector, despite the limited overall number of available declarations. Nevertheless, one company has published the highest number of EPDs (18), followed by another company (eight), while all other companies own a maximum of five EPDs.

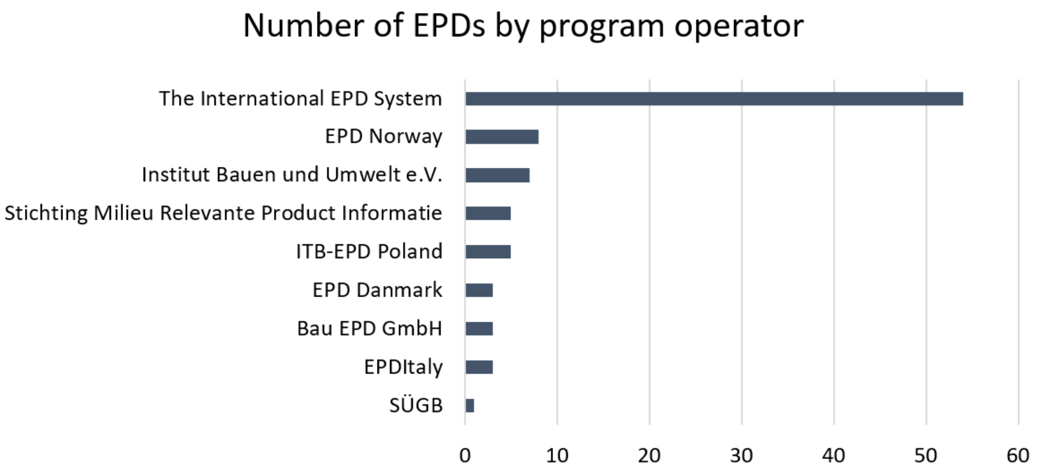

Figure 2: Number of reviewed EPDs for railway infrastructure products by program operator.

3.2 EPD Types and Data Usage

As illustrated in Figure 3, the reviewed EPDs comprise several types, with product-specific declarations clearly dominant, suggesting a high level of manufacturer engagement and potentially detailed, product-level data available in the railway infrastructure sector. However, as highlighted in previous studies [11, 19, 24], increased granularity does not necessarily improve comparability and usability for decarbonisation if methodological consistency is lacking.

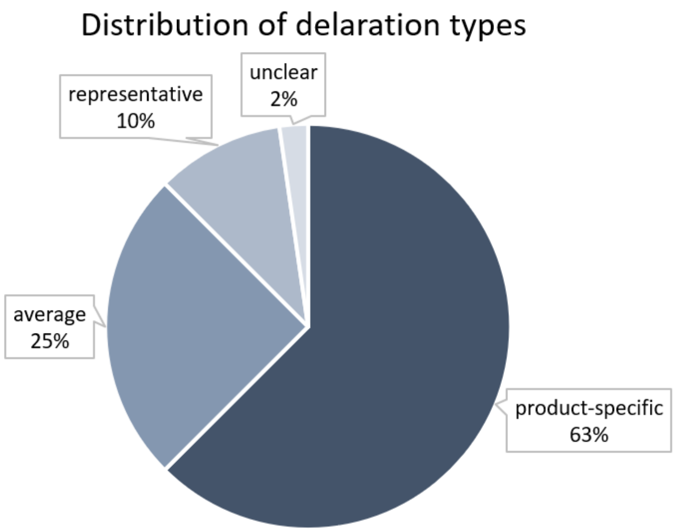

Figure 3: Percentage distribution of declaration types of reviewed EPDS for railway infrastructure products.

By contrast, 22 EPDs represent average EPDs, describing the mean environmental performance of multiple products or manufacturers. A small number of EPDs were identified that use representative data from one product. For 2 % of the EPDs, the declaration type could not be clearly determined based on the available documentation and was therefore classified as unclear.

All of the reviewed EPDs rely on established life cycle inventory databases for background data. The majority (71 %) use the ecoinvent database, while 28 % are based on the GaBi database from Sphera. One EPD reported using both ecoinvent and GaBi as background databases. Within the group of ecoinvent-based EPDs, nearly all declarations rely on ecoinvent version 3, although different sub-versions between v3.5 and v3.10 were applied across manufacturers. One manufacturer published multiple EPDs based on ecoinvent version 2.2, released in 2010, which can be considered an outdated version.

Although the dominance of ecoinvent suggests a certain degree of convergence, the variation in versions and the continued use of outdated challenges the robustness of results, as identified by Modahl et al. [27]. For decarbonisation pathways that rely on benchmarking or target setting, such inconsistencies undermine confidence in EPD-based comparisons.

3.3 Geographical Representativeness

As railway infrastructure is highly national due to different regulations, the geographical coverage of EPDs is crucial. The largest share of EPDs are limited to individual countries (59.5 %), which are mapped in Figure 4. These are followed by EPDs representative of Europe as a whole (24.7%), and globally representative declarations (11.2%).

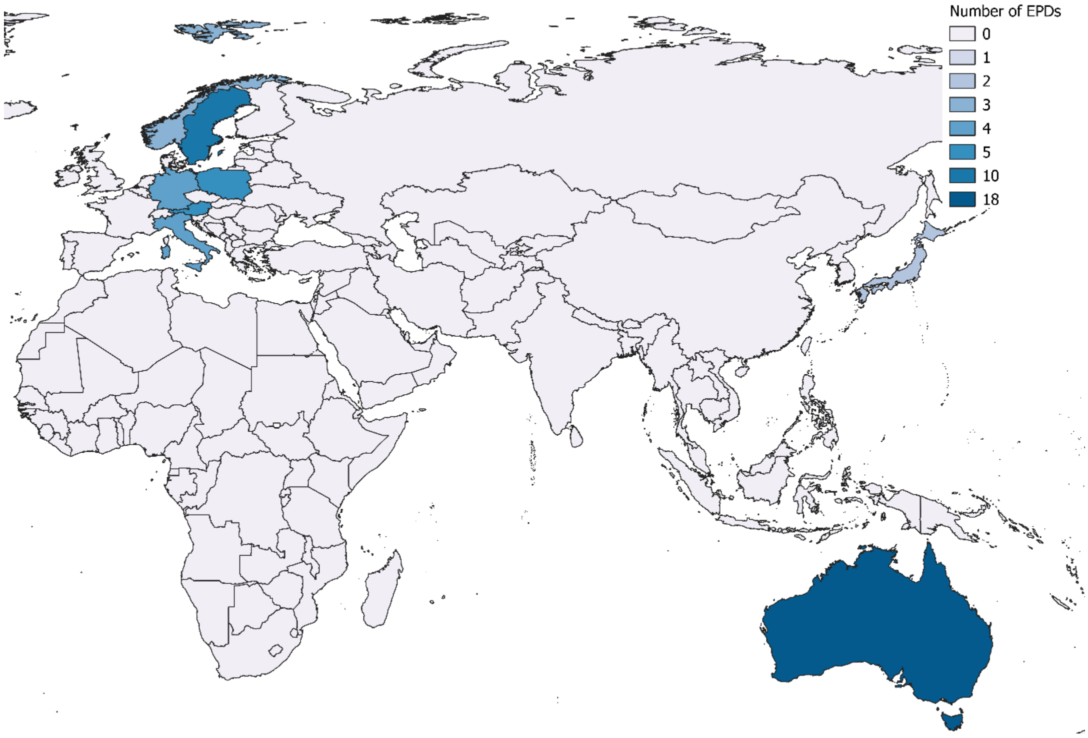

Figure 4: Geographical distribution of reviewed country-specific EPDs for railway infrastructure products.

From the individual countries the largest number of EPDs are intended for the Australian market, due to one manufacturer providing multiple EPDs for marketing there. Four EPDs provided unclear or insufficient information regarding their geographical representativeness. Overall, the distribution indicates a concentration of EPD development in Europe and selected international markets, with uneven geographic coverage across regions.

3.5 Declared Life Cycle Modules

As illustrated in Figure 5, the analysed EPDs exhibit considerable variation in the extent of declared life cycle modules. The most common life cycle coverage is cradle-to-gate with end-of-life stages (A1-A3, C1-C4 and D), which corresponds to the current EN 15804+A2 standard requirements. In addition, twelve EPDs provide a full life cycle coverage (A–D), encompassing production, construction, use, end-of-life, and benefits beyond the system boundary.

A substantial number of EPDs extend coverage to include construction-stage modules, while the use stage is barely included. Several EPDs display unique or uncommon combinations of life cycle modules, which limits comparability, and not all are compliant with EN 15804 + A2. However, only three of the EPDs that do not comply with the standard claim to do so. The others either fall into the electronic components category and comply with EN 50693, or were published under the previous EN 15804 + A1 standard, which only required a cradle-to-gate analysis.

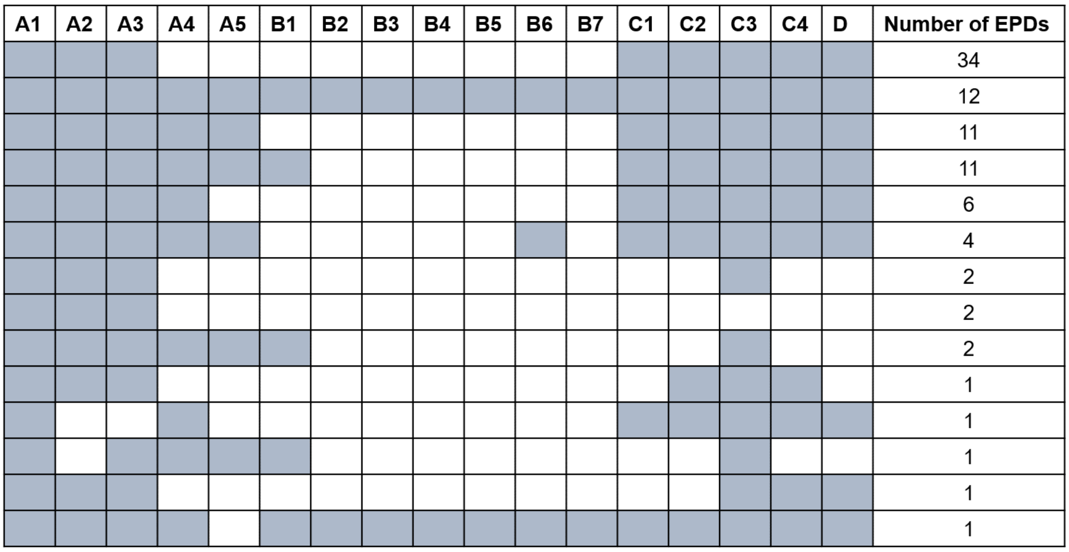

Figure 5: Mapping of declared life cycle modules across the reviewed EPDs.

The variation in declared life cycle modules significantly limits the integration of EPDs into decarbonisation strategies. While adherence to EN 15804+A2 ensures at least partial comparability, the frequent omission of construction and use-stage modules reflects a broader challenge in transferring building-oriented assessment frameworks to infrastructure systems. In the railway context, the limited inclusion of use-stage modules is particularly problematic, given the significant role played by long service lives, maintenance cycles and replacement in life-cycle emissions [33, 38].

3.4 Product Types and Associated Product Category Rules

The analysed EPDs cover a range of product categories relevant to railway infrastructure, with a particular concentration on track-related components. The largest number of EPDs relates to sleepers, while all other categories are moderately represented, including structural concrete and concrete elements, electronic components and track-related systems such as rail fixations, track bed materials, turnouts, and rails.

This uneven availability of EPDs for different product groups constrains the systematic use of EPDs in railway-specific decarbonisation strategies. The high number of EPDs for sleepers reflects their material intensity and established role in embodied carbon assessments. However, rails, which are among the components with the highest global warming potential in railway tracks [38, 39], are underrepresented relative to their importance.

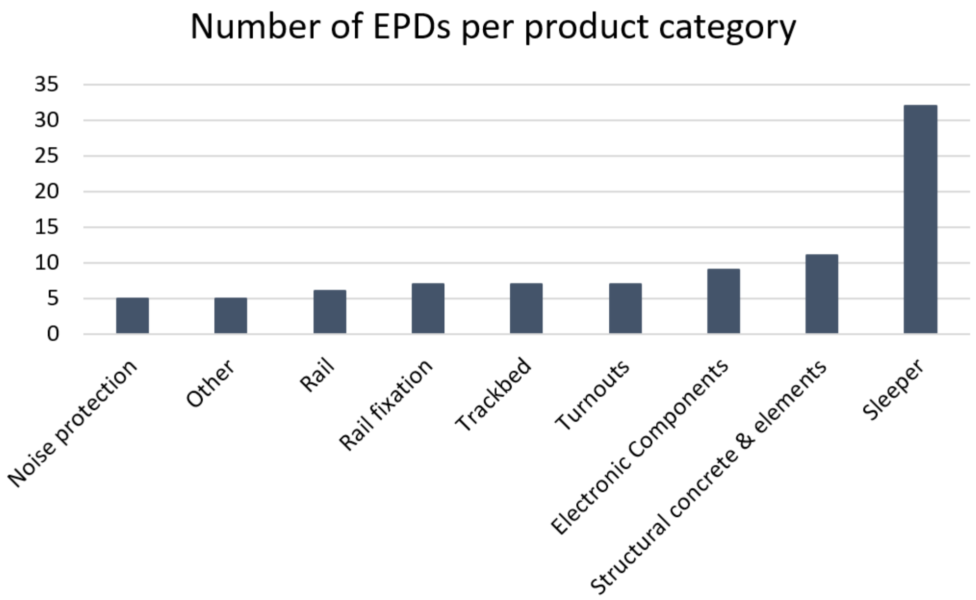

Figure 6: Number of EPDs per railway infrastructure product category included in the analysis.

The EPDs apply a diverse set of PCRs. In total, twelve distinct PCRs were identified across the dataset, originating from seven different POs, which represents only a subset of the POs covered by the reviewed EPDs. The reason for this is that EPDs published by Stichting Milieu Relevante Product Informatie did not reference additional PCRs beyond EN 15804 as the core PCR, and that concrete products published under EPD Denmark referred to the Danish standard DS/EN 16757:2017, which specified product category rules for concrete and concrete elements before its withdrawal.

The use of a PCR developed by a different PO on the basis of mutual recognition agreements was limited, even though such agreements exist between a large number of the POs examined. Such cross-operator PCR application was observed in five cases, where PCRs from EPD Italy were used for EPDs published under EPD Norway.

The most frequently applied PCR is PCR 2019:14 for construction products from the International EPD System. This corresponds to the comparatively high number of EPDs published under the International EPD System in the reviewed dataset. In contrast, railway-specific PCRs were rarely applied. Only two EPDs, both addressing rail fixation components, used PCR 2013:19 "Railways" from the International EPD System, and in both cases this PCR was applied in addition to PCR 2019:14. Five EPDs for rails applied the PCR "Rails forming a track for vehicles" from Institut Bauen und Umwelt e.V. No EPDs were found to apply the c-PCR for railway infrastructure. Although this approach facilitates the development of EPDs through the use of established frameworks, it does not consider the functional, operational, and system-specific characteristics of railway infrastructure.

Generally, c-PCRs were applied exclusively to concrete products and sleepers. All of these referenced c-PCR 003 "Concrete and concrete elements" in conjunction with PCR 2019:14 from the International EPD System. In general, concrete products were found to rely on more specific PCRs compared to other railway infrastructure components, with concrete-related EPDs consistently referring to concrete-specific PCRs rather than generic construction product rules across different POs.

The analysis indicates that multiple PCR frameworks are applied in parallel for the same product categories, which supports that concerns raised in the literature regarding PCR fragmentation [11, 19, 23] are also present in railway infrastructure EPDs. Figure 7 provides an overview of the applied PCRs in the different product groups.

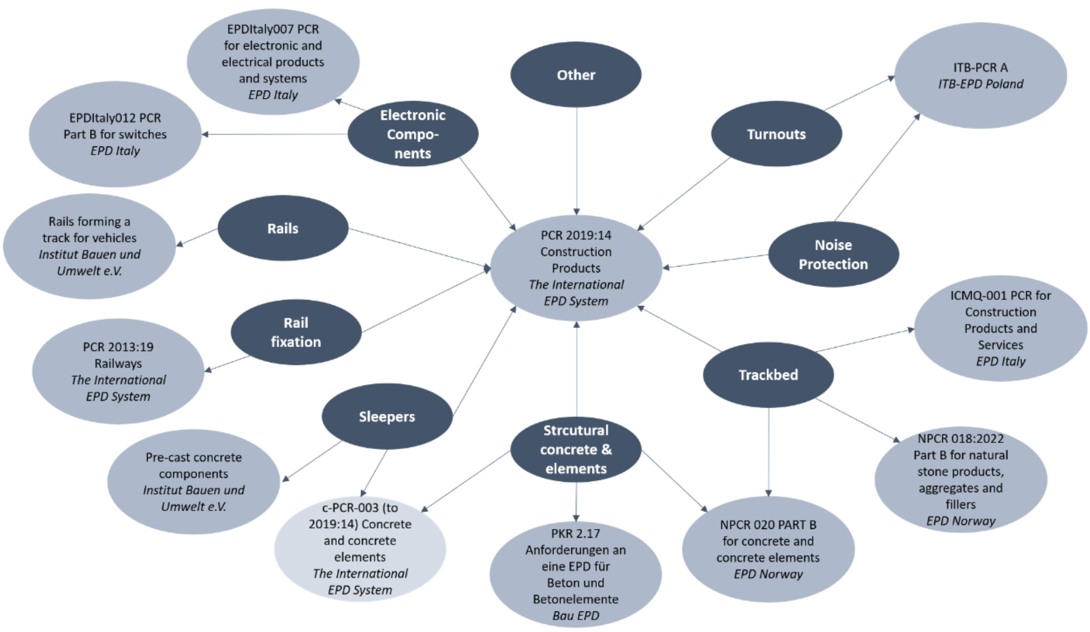

Figure 7: Mapping of railway infrastructure product categories to applied PCRs across the reviewed EPDs.

4 Conclusions

This study assessed the role of EPDs in supporting the decarbonisation of railway infrastructure by analysing EPD availability, and methodological characteristics across key product categories. The results show that while EPDs are increasingly available for selected railway components, their uneven distribution and methodological heterogeneity currently limit their effectiveness as a system-wide decarbonisation tool.

EPD coverage is concentrated in a small number of product categories, particularly concrete-based products such as sleepers, while several critical railway infrastructure elements, including rails, turnouts, noise protection systems, and track bed components, remain underrepresented. Differences in EPD types, applied PCRs, background databases, geographical representativeness, and life cycle coverage further reduce comparability and constrain the use of EPDs for design optimisation and carbon-informed procurement. These findings indicate that current EPD practices largely reflect the transfer of material-oriented assessment approaches from the building sector, rather than addressing the functional and system-level characteristics of railway infrastructure.

As a result, the current EPD landscape primarily supports decarbonisation at the product or material level. Where EPDs are available for multiple alternatives within a product category, they enable life-cycle-based material selection and targeted optimisation. However, limited or fragmented availability restricts design choices and reduces the feasibility of infrastructure-wide assessments and procurement strategies that rely on consistent environmental data across multiple components.

Overall, EPDs present a necessary foundation for carbon transparency in railway infrastructure but remain an incomplete instrument for comprehensive decarbonisation. Expanding EPD coverage across railway components, strengthening railway-specific PCR frameworks, and improving methodological harmonisation and life cycle completeness are essential to enhance their role in enabling effective decarbonisation strategies.

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