Life Cycle Assessment of a Large-Scale Rail Infrastructure Project: A Case Study of ABS 38

Master's Thesis of Mohamed Elzahani

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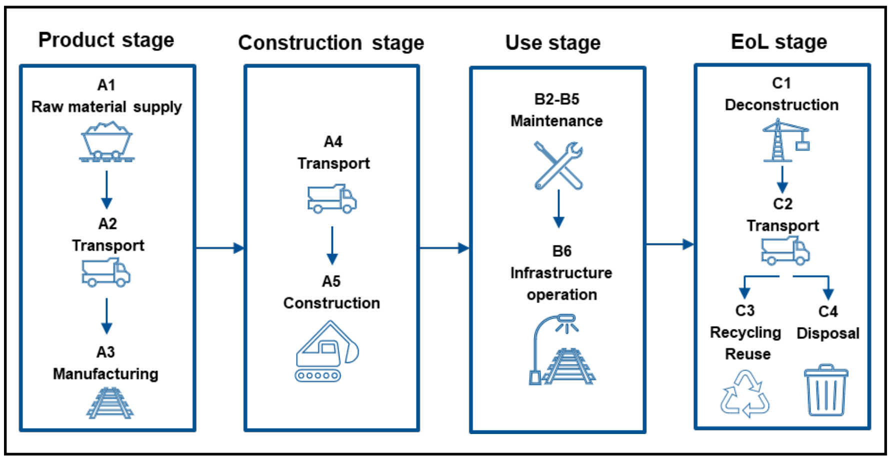

Fig. 1 System boundary diagram for rail infrastructure LCA study

Introduction: The EU's transport sector accounts for a significant portion of energy-related greenhouse gas emissions, but efforts to reduce these emissions have been challenging. To meet international obligations, like the Paris Agreement, EU member states are required to implement national measures to address these emissions. The 2030 Federal Transport Infrastructure Plan (FTIP 2030) aims to lower emissions by promoting low-carbon transportation, especially high-speed rail (HSR). However, assessing the climate impact of the transport system must encompass not only the operation of rolling stock but also the construction and maintenance of infrastructure.

The purpose of this Master's thesis is to develop a comprehensive Life Cycle Assessment (LCA) model, providing a holistic approach to estimating GHG emissions associated with the entire life cycle of HSR infrastructure in the context of Germany. This model is applied as a case study to the planned HSR line ABS 38, assessing its environmental impact in CO_2-equivalent (CO_2-eq) as an indicator of the climate impact of Global warming potential (GWP). Additionally, this thesis employs the developed LCA model to calculate the net CO_2-eq emissions of the proposed HSR line, aiming to determine whether the infrastructure project justifiably reduces environmental impact compared to alternative transport modes for this line, see **Fig. 2**.

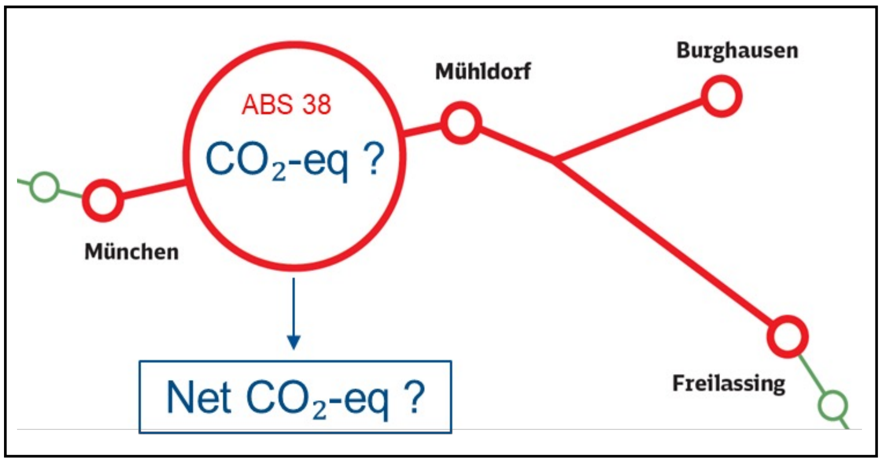

Fig. 2 The overall aims and scope of the Master's thesis

The system boundary of the developed LCA model follows the modular structure of c-PCR-023, adhering to the framework of Environmental Product Declarations (EPDs) in accordance with ISO 14040, ISO 14044, EN 15804+A2, and ISO 21930 for building-related construction products and services. Data sources include relevant EPDs, Deutsche Bahn, and a comprehensive literature review. The framework covers a complete railway infrastructure construction project, including tracks, stations, bridges, and overhead cables, and masts, see **Fig. 1**

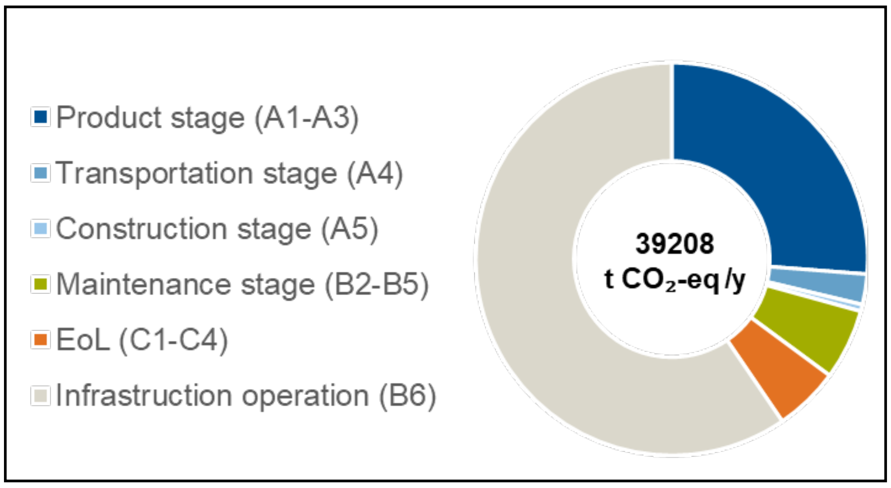

Fig. 3 The overall aims and scope of the Master's thesis

Results reveal that Module B6, infrastructure operation, contributes the most significant impact during the life cycle of the ABS 38 infrastructure line, accounting for 60 % of emissions, followed by product stage modules (A1-A3) at 26 %. Maintenance modules (B2-B5) and End-of-Life modules (C1-C4) also generate substantial GHG emissions. Construction stage modules (A4-A5) have a comparatively lower impact, see **Fig. 3** ABS 38's infrastructure demonstrates a notable capacity to mitigate GHG emissions by promoting passenger modal shift. However, increasing the modal shift to the rail freight corridor is essential to achieve a payback time shorter than the project's 60-year lifespan and a net negative impact. Policymakers have a responsibility to attract more freight to HSR, bridging the current freight demand gap.

In conclusion, this research advances our understanding of the environmental impacts of HSR transport from a life cycle perspective. The findings offer insights for rail planners in anticipating the potential consequences of achieving low-carbon emission objectives within the transport sector.

Limitation: Module D is not addressed. However, it is mandatory to be included in developing a certified EPD for the infrastructure line and to understand benefits and loads beyond the system boundary. Limited exploration of the impact of rough terrain on LCA results suggests that constructing railways in such areas could result in higher environmental costs. Uncertainty analysis is not addressed, but performing methods such as Monte Carlo analysis is critical for a more reliable and comprehensive assessment of the uncertainty in the calculations.