LCA and LCC Integration for Supporting Decisions in the Design and Construction of Sewer Networks in Future Smart Cities

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Abstract

Purpose: Given that the current urbanisation patterns increase the demand for sanitation infrastructures, this study aims to assess the eco-efficiency of constructing sewers in small to medium sized cities.
Methodology: To do so, the environmental and economic costs related to the construction of sewers were analysed using Life Cycle Assessment (LCA) and Life Cycle Costing (LCC). Different pipe materials (i.e., concrete, high-density polyethylene (HDPE) and polyvinyl chloride (PVC)) and trench designs (i.e., with concrete, sand and mixed beddings) were compared.

Results and discussion: In general, concrete pipes scored better in environmental and economic terms, being up to 70-80% better than other designs. However, applying plastic pipes with sand beddings results in the lowest eco-efficiency because they present higher construction costs.
Conclusions: This life-cycle integrated approach might help urban planners in the decision-making process. When designing, expanding or rehabilitating sewer networks, this information provides guidance on how to improve the eco-efficiency of the system.
Keywords: sewer, eco-efficiency, LCA, LCC, construction

1 Goal and Scope

Considering the development of new settlements, the construction and rehabilitation of sewer networks is required to meet the demand for sanitation. Hence, implementing sustainable criteria is key in order to reduce the demand for current and future material and energy sources and the emission of pollutants.

This study aims **to couple LCA and LCC** with the objective of proposing indicators that can be used in the **design and construction of sewers from an eco-efficiency viewpoint.** The scope of the analysis is shown in Figure 1.

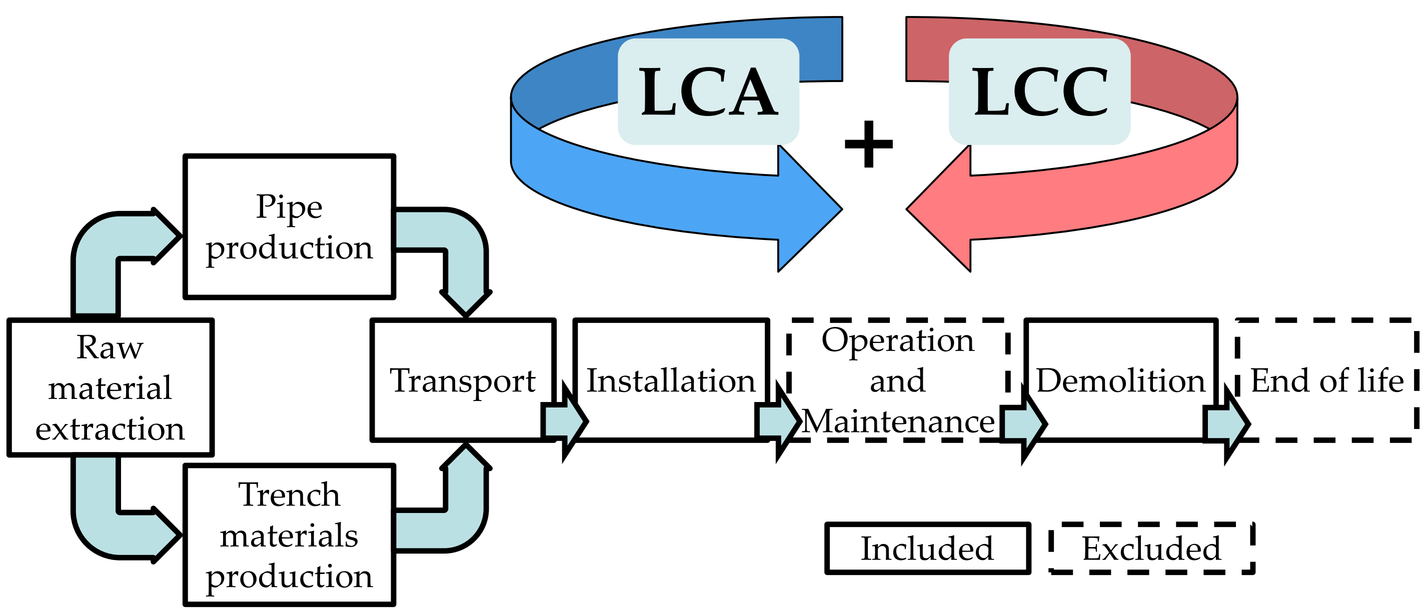


Figure 1. Diagram of the system boundaries

2 Methodology

LCA and LCC methodologies were applied following the ISO 14040 [1] and the methodology presented by Termes-Rifé et al. [2], respectively.

Functional Unit: 1 linear metre of sewer pipe with a diameter of 300 mm.

The selected **constructive solutions** are shown in Figure 2, which represent the most common designs. The lifespan of concrete pipes was 100 years, whereas 50 years were considered for PVC and HDPE [3].

Databases: Prices and material quantities were retrieved from MetaBase ITeC [4]. For the LCA, ecoinvent 2.2 was used, linked to Simapro 7.3.

Methods: CML 2 baseline 2000 V2.05, Cumulative Energy Demand v1.08.

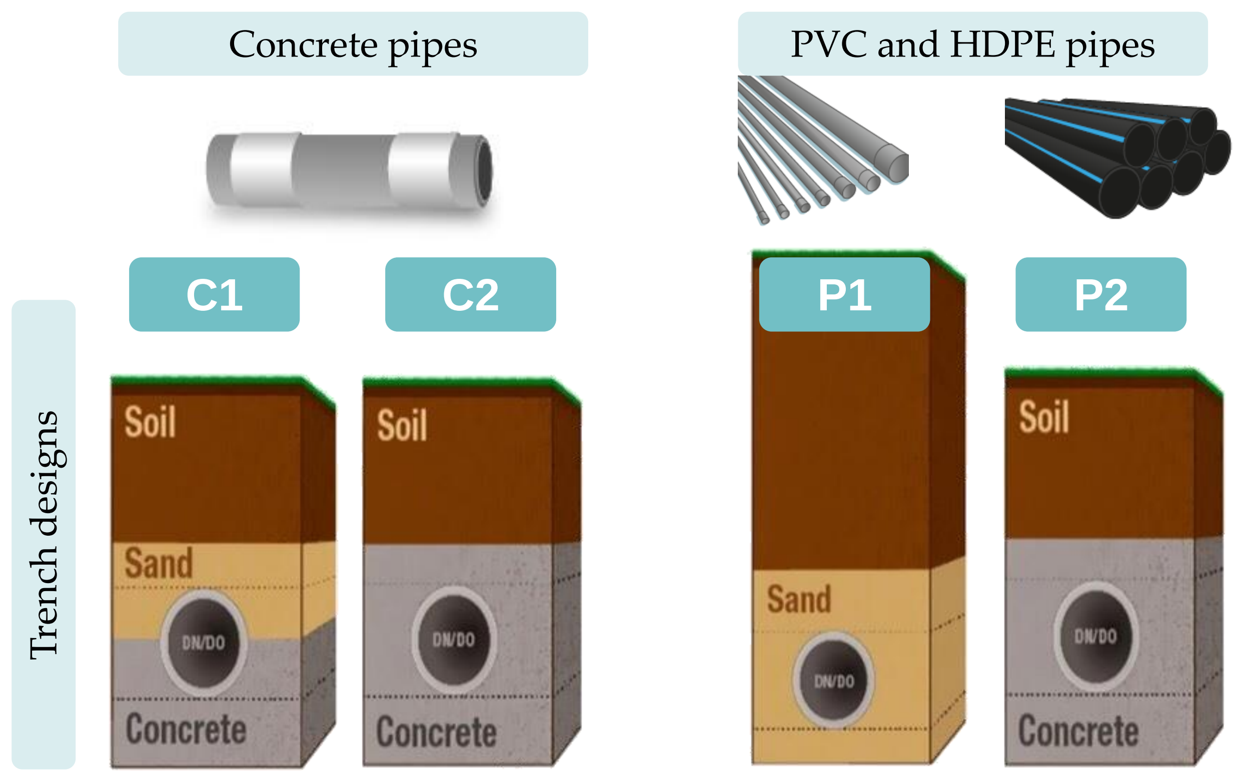
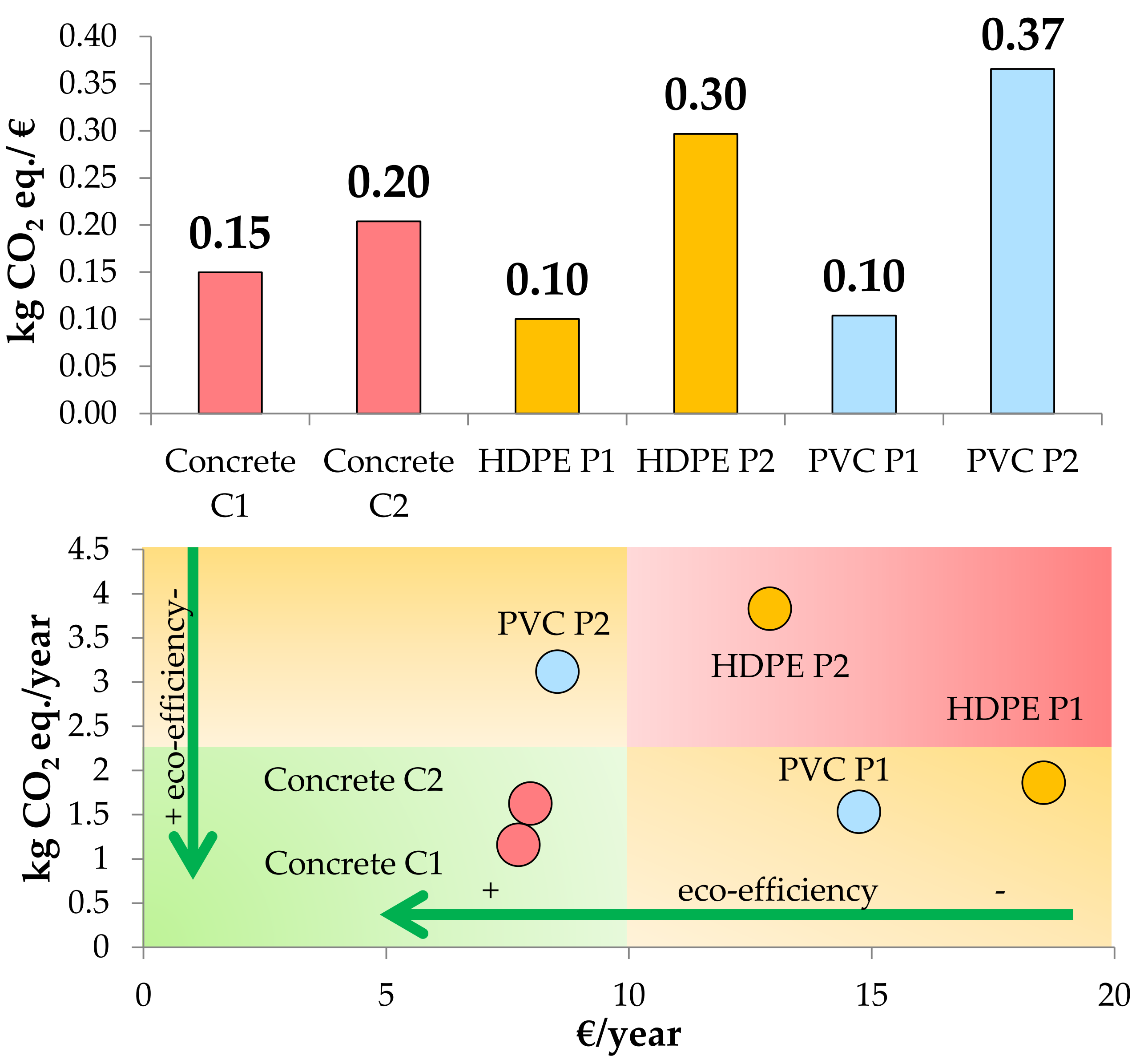


Figure 2. Pipe and trench designs

3 Results and Conclusions

In general, **concrete pipes are the most eco-efficient option** due to their longer lifespan and pipe composition (70-80% better than the worst option). In the case of plastic pipes, results differ between trench designs. P1 is more expensive and has fewer emissions, whereas P2 has more emissions and fewer economic costs. This results in P2 having greater kg CO_2eq. per euro (0.30-0.37 kg/€) (Figures 3,4). The elements that contribute to this difference are the construction materials and the depth of the trench.

Hence, when planning sewer networks, decision-makers should not only consider the technical feasibility of each pipe material, but also the economic and environmental impacts associated with each design. The overall eco-efficiency of the system might be improved by accounting for the lifespan of the materials, the optimisation of the trench design and the site specific features (i.e., soil composition, land use).



Figures 3 and 4. Eco-efficiency ratios and benchmarking diagram

4 References

[1]ISO. International Organization for Standardization. Environmental management—life cycle assessment —principles and framework. International Standard 14040; Geneva, 2006.
[2] Monserrat, T.-R.; María, M.-S.; Francesc, H.-S.; Ramón, S.-G. Life cycle costing: a tool to manage the urban water cycle. J. Water Supply Res. Technol. 2013.
[3] U.S. Army Corps of Engineers. Engineering and Design. Conduits, culverts, and pipes. Engineer Manual 1110-2-2902; Washington, DC 20314-1000., 1998.
[4] MetaBase ITeC. Online ITeC database: prices, technical details, companies, certificates, product pictures and environmental data http://www.itec.cat/metabase.

5 Acknowledgements

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