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Integrating life-cycle assessment into transport cost-benefit analysis

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Abstract

Traditional transport Cost-Benefit Analysis (CBA) commonly ignores the indirect environmental impacts of an infrastructure project deriving from the overall life-cycle of the different project components. Such indirect impacts are instead of key importance in order to assess the long-term sustainability of a transport infrastructure project. In the present study we suggest to overcome this limit by combining a conventional life-cycle assessment approach with standard transport cost-benefit analysis. The suggested methodology is tested upon a case study project related to the construction of a new fixed link across the Roskilde fjord in Frederikssund (Denmark). The results are then compared with those from a standard CBA framework. The analysis shows that indirect environmental impacts represent a relevant share of the estimated costs of the project, clearly affecting the final project evaluation. Additionally, they can significantly modify the weight of the different components of the overall project costs – evidently becoming a significant part of the estimated construction cost. Therefore, the suggested approach guarantees a higher quality of information thus providing decision makers with a more thorough insight of the environmental impact of the project.

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Keywords: life-cycle assessment; cost-benefit analysis; sustainability; transport models; decision support modelling

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1. Introduction

Based on the outcome from the Brundtland report (UN, 1987), Holden et al. (2013) derived four main dimensions of sustainable development: satisfaction of human needs, intra- and intergenerational equity and long-term ecological sustainability. Having the latter dimension in mind, it can be argued that traditional transport project evaluation frameworks commonly fail to provide decision makers and stakeholders with a complete picture of the full environmental costs deriving from the implementation of transport projects. In fact, while the direct environmental costs, such as air pollution from vehicles operation, are normally included in the project evaluations, the indirect environmental costs, such as the energy and emissions associated with vehicle manufacturing, are usually not. Herein, the indirect environmental costs are identified as those deriving from the life-cycle of the project components, commonly quantified through Life-Cycle Assessment (LCA) techniques. In synthesis, LCA is the assessment of the environmental impact of a given product or process throughout its lifespan (ISO 14040, 2006) and it is mainly used to compare different products or processes whereafter the one with the least ecological footprint can be prioritised. The standard LCA framework has four steps and includes goal definition and scoping, inventory analysis, impact assessment and interpretation (Kloepffer, 2008). The environmental impact is assessed with a holistic approach spanning throughout the entire lifespan of the product or process, including raw material extraction and processing, manufacture, distribution, use, maintenance, recycle and disposal. LCA analyses are based on the information provided by life-cycle inventories, where the environmental impacts of a product or a process are first defined through a system modelling approach and then quantified. Eventually, the aim of LCA is to quantify the overall life-cycle environmental impact of a product or process, in terms of both resources taken from and released to the ecosystem.

The use of LCA methods in transport studies is primarily seen by the authors as a tool to inform decision makers and help as they develop strategies to meet environmental and sustainability goals. Part of the existing literature focuses on the different environmental impacts deriving from different transport modes. Chester and Horvath (2009) use LCA to analyse passenger transport in the US considering car, buses, trains and airplanes. They find that life-cycle energy inputs and greenhouse gas emissions increase the vehicle operating costs from 31% (air) to 155% (rail). Chester et al. (2010a) make a comparative energy and emission transport LCA for three US metropolitan regions. The results show that the inclusion of life-cycle environmental impacts results in significant increases in terms of energy consumption and emissions, up to 20 time that of vehicle operation for all modes. Some of the studies on the field use an integrated approach combining transport and land use frameworks. Kimball et al. (2013) implement such an approach to quantify long-term impacts from land use and public transport (transit oriented) policies. They highlight how environmental effects from building construction, vehicle manufacturing and energy feedstock are significant.

LCA is also used in the literature to quantify the indirect environmental costs of building transport infrastructure projects. Park et al. (2003) use a LCA to investigate indirect costs of highway constructions, where environmental impacts are estimated based on the energy consumption. The results show that the highest amount of energy is used in the manufacturing stage of construction materials, followed by maintenance and repair stages. Chester and Horvath (2010b) apply LCA on transport modes in the California corridor, comparing existing modes with the high speed rail system planned to be constructed by the State of California. The results show that, due to the required new infrastructure building process, the high-speed rail connection may or may not produce fewer environmental burdens depending of the actual future ridership. Thoft-Christensen (2011) uses LCA to analyse a motorway infrastructure case study. The results demonstrate that design and maintenance costs of a new infrastructure can be expected to be higher than those of repair or enhancement of an existing one. Chester et al. (2013) implement a LCA to analyse near-term and long-term sustainability effects of transport modal shift from private to public transport (transit oriented). The results show that the life-cycle of the infrastructure, vehicle and energy production components significantly increases the footprint of each mode, although authors argue that emerging technologies may reduce the impacts.

Despite transport LCA studies clearly indicate the importance of the indirect environmental impacts in assessing transport sustainability, with the partial exception of Thoft-Christensen (2011) no attempts have been made to define the effect of integrating LCA into standard transport Cost-Benefit Analysis (CBA). Building on the existing literature, the aim of the present study is to fill this gap by, first, outlining a framework combining LCA and CBA