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Assessing the environmental impact of inland waterway transport using a life-cycle assessment approach: The case of Flanders

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ABSTRACT

Focus in determining the environmental component of external transport costs has been mainly directed towards vehicle travel related emissions, while more indirect emissions related to well-to-tank operations, vehicle fleet and transport infrastructure received less attention. Especially for inland waterway transport, little research exists in this domain.

In this paper, a life-cycle assessment (LCA) based framework is recommended in order to assess the full environmental impact of inland waterway transport services. Environmental emissions (both air polluting and greenhouse gas emissions) for barge transport are analyzed in detail for one particular geographical region, namely Flanders (in Belgium), applying an LCA approach.

Three distinct categories are being considered: emissions directly related to vehicle operation (both “tank-to-wheel” and “well-to-tank” emissions), emissions related to barge fleet (building and maintenance of barges) and emissions related to transport infrastructure (construction, operation and maintenance of waterway infrastructure). This approach allows to map environmental emissions for different transport components in much greater detail and enables to determine their relative importance. The analysis also shows that for some pollutants, taking into account other categories besides vehicle travel is relevant from a sustainability perspective.

1. Introduction

Next to large economic and social benefits, transport services also cause significant, mostly negative, external costs, defined by Bickel and Friedrich (2005) as:

> “An external cost arises, when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group.”

A rather impressive list of external costs is associated with transport activities, caused by emissions (climate change effects and air pollution), accidents, noise, soil contamination, interference in the ecological system, damage to infrastructure, visual nuisance, congestion and effects associated with up and downstream processes, such as extraction, refining and transport of fuels (pre-combustion processes) and construction, maintenance and scraping of vehicles and infrastructure (Maibach et al., 2008). These external costs cause transport market prices to not fully reflect the societal cost of transport services, resulting in transport activity levels generally above social optimum. This market mechanism's failure to achieve social optimum can provide a rationale for government intervention (Schmidtchen et al., 2009). European transport policy as advocated by the European Commission proposes an internalization of external costs in order to initiate a shift from less to more sustainable transport services and achieve more socially optimal transport decisions by stakeholders (European Commission, 2011). A correct assessment of negative externalities is however a crucial but complex element in such an approach.

In this paper, the focus will be on transport related air emissions, which can be divided in two broad categories. On the one hand emission of air pollutants such as particulates (particulate matter $PM_{2,5}$ and PM_{10}), nitrogen oxide (NO_x), sulfur dioxide (SO_2), heavy metals and volatile organic compounds (VOCs). Air pollution related external costs include impacts on human health, impacts on materials and buildings, damages to agricultural crops and costs for further damage to ecosystems (biosphere, soil, water, forests). Health costs (mainly caused by particulates, emission of exhaust gases or transformation of other pollutants) are by far the most important air pollution external cost category (Maibach et al., 2008). On the other hand there are emissions of greenhouse gases (GHG) such as carbon dioxide (CO_2), nitrogen oxide (N_2O) and methane (CH_4). Social costs of climate change are described in literature as rising sea levels, modified energy use (changes in need of heating), agricultural impact, need of drinking water, health impact, ecosystems and biodiversity, extreme weather situations and increase of so-called “major events” (such as change in the Gulf current, collapse of the Amazon forest, methane explosions, and alteration of the monsoon

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season). Estimation of climate change costs is characterized by high complexity when predicting long term effects on a global scale and risk patterns which are hard to anticipate (Maibach et al., 2008).

With regard to environmental emissions of transport modes, scientific literature and policy makers still mainly focus on vehicle travel related emissions. However, in order to effectively mitigate environmental impacts from transportation modes, life-cycle environmental performance should be considered including both direct and indirect processes and services required to operate the vehicle, taking into account raw material extraction, manufacturing, construction, operation, and maintenance, and end of life of vehicles, and infrastructure and fuels (Chester & Horvath, 2009).

In order to assess full environmental sustainability of a transport service with regard to emissions, a life-cycle assessment (LCA) based methodology is therefore recommended (Chester & Horvath, 2009; Pettersen, Bergsdal, Hung, & Solli, 2011; Spielmann, Bauer, Dones, Scherrer, & Tuchshmid, 2007).

The structure of this paper comprises two main parts. First, a literature study is performed to identify current academic knowledge on transport related LCA's. Based on this literature study, an LCA-based framework is proposed to map transport related emissions. Secondly, the proposed methodology is applied to inland waterway (IWW) transport in Flanders, in order to derive specific emission factors for different GHG and air pollutants, differentiated by barge type and per waterway class, and this for different transport service components (vehicle operation, vehicle fleet and transport infrastructure). In this way, relative importance of the different components can be compared on different dimensions (e.g. for different pollutants, for different barge types, for different waterway classes) and environmental impact of IWW transport related emissions can be assessed in much greater detail. To finish, conclusions and further research goals are formulated.

2. Transport related life-cycle assessments

This section consists of three parts. Firstly, background and theoretical concept of life-cycle assessment is shortly described. Secondly, scientific literature with regard to transport related life-cycle assessments is summarized. Thirdly, findings from literature that are relevant for applying an LCA-based framework to map emissions of transport services are identified and a framework to map the emissions of a transport service is discussed.

2.1. Life-cycle assessment: background and theoretical concept

Frischknecht (1998) defines life cycle assessment (LCA) as a method for analysis and assessment of potential environmental impacts along the life cycle of a good or a service. An LCA is, according to Frischknecht (1998)

> "[…] applicable on products, processes or firms, to document their environmental performance, to identify potentials for environmental improvements, to compare alternative options as well as to substantiate ecolabelling criteria."

LCA takes into account a product's full life cycle from extraction of resources, through production, use and recycling, up to disposal of remaining waste (Institute for Environment & Sustainability, 2010). Life cycle assessment is therefore considered to be a vital and powerful decision support tool, complementing other methods, which are equally necessary to help effectively and efficiently make consumption and production more sustainable (Institute for Environment & Sustainability, 2010).

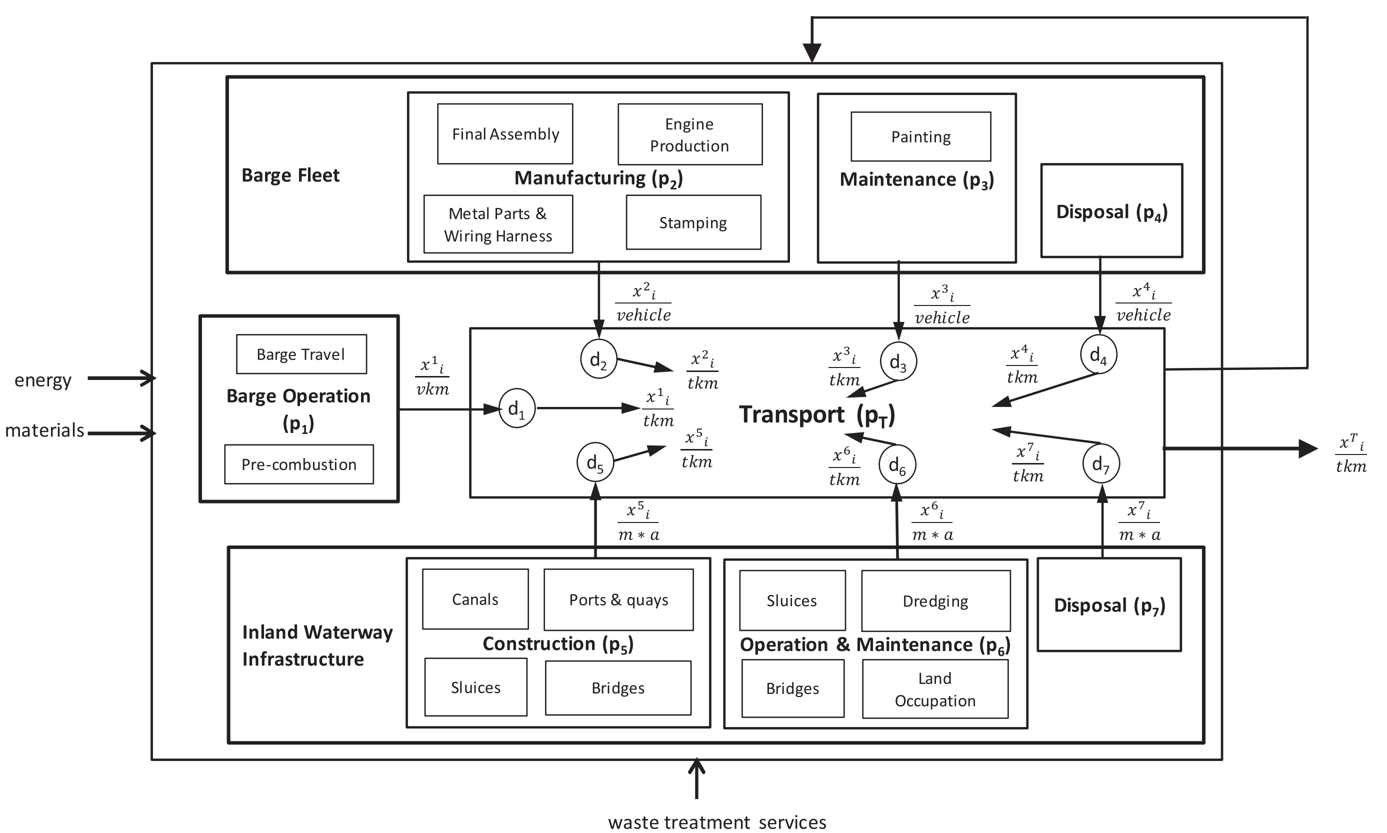

Fig. 1. Life cycle inventory of inland waterway transport (own setup based on Spielmann & Scholz, 2004).