Journal of Cleaner Production 90 (2015) 163–170

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Review

Life cycle assessment for the green procurement of roads: a way forward

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ARTICLE INFO

Article history:
Received 25 March 2014
Received in revised form
25 August 2014
Accepted 26 November 2014
Available online 4 December 2014

Keywords:
Life cycle assessment (LCA)
Green procurement
Attributes
Roads
Energy

ABSTRACT

Life cycle assessment (LCA) methodology can be used to assess the environmental impacts of a road system over its entire life time. However, it is very important to align the potentials and limitations of such tools with their intended purpose. For the LCA to be useful for the decision support in a procurement situation, it should therefore be important to have a clear understanding of the technical features (attributes) that build up the life cycle phases. In this paper, different types of decisions situations are outlined based on at what level of complexity (network or specific project) and at what stage within the planning process (early planning or late planning/design) the decision is to be made, and relevant methodological choices for these decision situations are discussed. Further, the attributes that are important to consider in an asphalt road LCA that seeks to serve as a decision support in a procurement situation are suggested and technical features for these attributes are outlined with focus on Energy and GreenHouse Gas emissions. It can be concluded that in order to aid the implementation of green procurement, it would help if the attributes of the system are defined in a transparent manner and consistently calculated. It is, however, also important that the attributes should mirror the material properties used in a pavement design and therefore be closely linked to the performance of the road in its life time. It is also recommended to report the feedstock energy in the road LCAs.

1. Introduction

Road Infrastructure is an important asset for society that not only provides for mobility, but also enables economic growth. Good planning and design, combined with a careful selection of construction materials can significantly enhance the sustainability of a given road. The European Union (EU) is aiming to achieve a resource-efficient and low carbon economy for the sustainable growth by 2020. The two subjects highlighted for the future focus by the EU are to improve waste management by including all life cycle stages from extraction to disposal and reduce power consumption by increasing the energy efficiency (A resource-efficient Europe, 2011). Life cycle assessment (LCA) methodology can be used to assess the environmental impacts of a road system over its entire life time and results can be very helpful in taking major decisions at the network and the project level. Studying the life cycle perspective of roads can help us improve the technology in order to achieve a system that has a lower impact on the environment.

Baumann and Tillman (2004) have distinguished three types of LCAs; Stand-alone LCA, change/effect oriented or consequential (CLCA) and accounting/descriptive type or attributional (ALCA) (Table 1). Stand-alone LCA is used to identify the environmental hot spots within a system and it reports the actual environmental declaration of a particular product. It could be used to identify the most energy consuming phase in a road's life cycle. CLCA is appropriate to use when changes within or outside the life cycle are studied by a change within a life cycle system (Ekvall and Weidema, 2004). Linearly modeled ALCA provides input and output flows attributed (associated) to the delivery of a specified functional unit (Rebitzer et al., 2004). It is a comparative approach that could be used as a decision support tool in a network or a project level based on how goal and system boundaries have been defined. According to Erlandsson et al. (2013), the use of LCA can be divided into the evaluation of the whole product systems where CLCA is used and the evaluation of individual products where ALCA is used. CLCA and ALCA are two different approaches that aim to answer different

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http://dx.doi.org/10.1016/j.jclepro.2014.11.068
0959-6526/

Table 1
Types of LCA (Baumann and Tillman, 2004).

LCA typeProducers/ LCA users	Standalone (descriptive)	ALCA (comparative and retrospective)	CLCA (comparative and prospective)
Policy makers/authorities	- Basis of development of producer take back schemes	- Governmental procurement - Development of eco-labeling criteria	- Basis for development of environmental policies (eg. IPP, and recycling schemes)
Industry	- Identifying "hot spots" - EPD	- Purchasing - Market communication - PCR development	- Product development - Process choices and optimization - Market communication

questions. Failure to differentiate between these two approaches may result in either wrong method being applied or a single assessment with mixed approaches or misinterpreted results (Brander et al., 2009). Selection of a certain LCA approach (standalone, CLCA or ALCA) largely depends on what decision level a study is being conducted and what are the goals to be achieved. The International Reference Life Cycle Data System (ILCD) handbook published in 2010 in a "science to decision support" process led by the Joint Research Center of the European Commission (EC-JRC), classified the decision context in the form of situation categories stated as 'A', 'B' and 'C' where different LCA approaches can be used. Micro-level decisions come under situation 'A' category and normally consider a specific product. Some of the examples are decisions for the product comparison, green public or private procurement, Product Category Rules (PCR) or Environmental Product Declaration (EPD) development etc. Macro/Meso-level decisions come under situation 'B' and are required for the policy information or development. Thus, they may consider a group of products or product types. Situation 'C' is mainly for retrospective accounting LCA studies.

Procurement is an acquisition phase when a product or service is bought. Due to the environmental and resource depletion concern, green procurement is of urgent need (Geng and Doberstein, 2008). The European Commission defines green public procurement as a process in which the public authorities procure products and services that have less environmental impact in a life cycle perspective when compared to the product and services that have the same function for which they could have been purchased (Buying Green, 2011). Green or sustainable procurement has, in fact, been discussed and promoted during the last couple of years in many developing and developed countries (Marron, 1997; Thomson and Jackson, 2007; Geng and Doberstein, 2008; Bolton, 2008; Walker and Brammer, 2009; Ho et al., 2010). LCA is an appropriate tool for integrating the environmental issues in a life cycle perspective in a procurement process (Hochschorner, 2004). LCA could help the purchaser to select a product or service based on the environmental aspects. Such purchasing choices will encourage the material producers and contractors to innovate and supply more resource efficient products and services (Roadmap to A resource-efficient Europe, 2011). When implementing tools for LCA within the procurement process, it is very important to align the potentials and limitations of such tools with their intended purpose.

Among the different LCA approaches, ALCA could be argued to be useful for the procurement purpose as it enables comparison between different products (Baumann and Tillman, 2004). However, in order to be able to compare and select certain alternatives within a transparent system, the EPD has to be created for that particular product. The PCR identifies and describes the process of preparing EPDs that reports the environmental data of the products making them comparable and verifiable. Preparing a PCR includes the definition of the criteria to be used in the LCA study of a product (Fet et al., 2009). PCR documents are prepared using standards such as the ISO or the industry standards. The ILCD handbook can also serve to be a parent document when preparing PCRs (ILCD, 2010). This handbook is in compliance with the ISO 14040-14044 standards and provides quality assurance and consistency in the life cycle studies.

The validity of LCA results is dependent on the quality of the data used (ILCD, 2010). For LCA to be useful for the decision support in a procurement situation, it should therefore be important to have a clear understanding of the technical features (attributes) that build up the life cycle phases and how the data of high quality for them are achieved. The aim of this paper is to describe the attributes that are important to consider in an asphalt road LCA for effective decision support in a late project planning stage leading into a procurement situation. Mass and energy input for these attributes are discussed. Mass of the construction materials in tonnes, energy (feedstock and expended, separately) in Joules and Green-House Gas (GHG) emissions in tonnes are the parameters focused while defining the attributes. As a basis, certain patterns regarding the life cycle stages, goals and system boundaries for the development of road LCAs were identified through a brief literature review of road LCA studies. The review focuses on the most cited and available online road LCAs. Feedstock energy consideration in road LCAs is also discussed in this paper.

2. Road LCA studies: a brief literature review

LCA can be used for different purposes within the field of transport infrastructure. Either the whole transport system can be studied, or the LCA can be applied on a single project or a component of a project. According to Stripple and Erlandsson (2004) three 'tiering levels' can be distinguished, including the network level, the corridor level and the project level. These different decision levels require different system complexities in order to answer the relevant questions that arise. There are some examples of corridor level and project level approaches in the LCA literature (Jonsson, 2007; Schlaupitz, 2008). However, project focused LCAs are more easily found. This literature review has been focused on project LCAs, and specifically those considering pavements, as this level is assumed to be appropriate for questions relevant in a procurement situation.

Pavement researchers started to use the LCA methodology in 1990s. In the literature, most road LCA studies are different road type comparisons (Häkkinen and Mäkelä, 1996; Horvath and Hendrickson, 1998; Mroueh et al., 2000; Stripple, 2001; Park et al., 2003; Athena Institute, 2006; Yu and Lu, 2012) but there are also examples on studies that focus specifically on either concrete roads (Evangelista and de Brito, 2007; Loijos, 2011) or asphalt roads (ECRPD, 2009; Vidal et al., 2013; Butt et al., 2014). There are continuously developments being made in the field of road LCAs (Pavement Life Cycle Assessment (LCA) Workshop, 2010, PCR, 2013). A summary of the focus identified in different published road LCA studies is shown in Table 2.

A lot of knowledge and data has been generated by the road LCA studies. However, it is prominent from the literature that comparative road LCAs is the most common scope that compares different