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Enhancing the practical implementation of life cycle sustainability assessment – proposal of a *Tiered approach*

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ABSTRACT

Life cycle sustainability assessment has been claimed to be one of the most common methods for assessing sustainability of products and processes. It consists of the three methods life cycle assessment, life cycle costing and social life cycle assessment. However, the life cycle sustainability assessment framework is still under development and its application is still limited. This is substantiated not only by the lack of data and experience, but also by the proliferation of indicators provided by different institutions. Although indicators are available for the three sustainability dimensions, guidance for the indicator selection is missing. The bottleneck is not the lack of good indicators, but rather the lack of a clear indicator selection process. This appears to be one of the most crucial aspects as data availability, method development and interpretation of results heavily depend on this issue. Another obstacle for the practical implementation of life cycle sustainability assessment arises with the relatively high entrance level. Whereas, for the environmental dimension sufficient data and simplified methods are usually available, e.g. carbon footprint, the social and economic dimension are lacking of similar simplifications. Within this study a *Tiered approach* has been developed providing an indicator hierarchy and proposing a stepwise implementation concept. An indicator review has been performed according to the three criteria practicality, relevance and method robustness. Afterwards the indicators have been ranked in three tiers. The first tier ('sustainability footprint') focuses on indicators, which are characterized as easily applicable indicators and as relevant for production processes and on global scales. The second tier reflects current best practice indicators already used in case studies and preferred by institutions. The last tier aims at giving a comprehensive set of sustainability indicators, even if this level may not be applicable immediately. The Tiered approach may not solve all challenges within life cycle sustainability assessment, e.g. the question of how to solve the interpretation dilemma still remains; however it does support the practical application and further development of the framework through the stepwise implementation of sustainability indicators. The application and science related benefits of the Tiered approach result from the undergone comprehensive indicator review, which seems essential as a basis for further developments within the life cycle sustainability assessment framework, and from the proposed indicator hierarchy, which provides directions for further research. The created sustainability footprint facilitates the practical implementation of life cycle sustainability assessment, as the entrance barrier was lowered without neglecting any dimension of sustainability.

1. Introduction

Sustainability and Sustainable development have been important topics in today's societies since they were promoted by the Brundtland Commission in 1987 (United Nations, 1987) and even earlier within the 'Limits to growth' (Meadows et al., 1972; The Club of Rome, 2014) and 'A blueprint to Survival' (Goldsmith et al., 1972). Sustainable development (SD) is connected to all areas of human life, even though its definition has not been unified yet. There is an ongoing discussion about the delimitation of sustainability and sustainable development as well as the achievement of sustainable development. The terms are often used as synonyms even if sustainable development can be seen as a (policy) principle and central notion, which is openly defined as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (United Nations,

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1987). On the contrary, sustainability is rather the property of a thing being sustainable (Heijungs et al., 2010).

Some argue that sustainable development rather follows the concept of weak sustainability (mostly in connection with the three-ring-model – addressing social, economic and environmental aspects), where trade-offs seem possible between the three dimensions (Giddings et al., 2002). Others by contrast state that SD goes beyond the weak sustainability concept via balancing the three dimensions (United Nations, 1987) and offers an attractive alternative to conventional growth-oriented development (Sneddon et al., 2006). Broad consensus has emerged about the contribution of social, environmental and economic aspects to sustainable development (Finkbeiner et al., 2010; Hacking and Guthrie, 2008; Heijungs et al., 2010). Additional dimensions, like cultural heritage or governance, are sometimes named, but have hardly been referred to within practical case studies. They also seem kind of irrelevant when focussing on the life cycle perspective, e.g. the proposed political-institutional (governmental) pillar is more related to organizations than to products (Burford et al., 2013). In addition, potential additional dimensions can often be covered within the social or economic dimension, e.g. cultural heritage has been mentioned as one possible pillar to measure sustainability (Burford et al., 2013), but has already been proposed as one impact category within the Guidelines of social life cycle assessment (Benoit and Mazijn, 2009). Hence, within this study the three common dimensions economy, environment and society have been selected to avoid diluting the assessment with too many side aspects (Hacking and Guthrie, 2008). The life cycle thinking concept plays an important role towards a practical implementation of sustainability aspects. Furthermore, a scientific life cycle based analysis is needed to avoid misuse of the term sustainable development (Heijungs et al., 2010). Therefore, within this study life cycle based sustainability assessment methods have been focused on.

Taking a closer look at the representation of sustainability aspects in practice it is conspicuous that most of the existing life cycle based methods still focus on only one of the three dimensions (e.g. life cycle assessment (Klöpffer and Grahl, 2014)) or are invalid from a methodological point of view (e.g. resource efficiency (Schneider et al., 2013)). However, with life cycle sustainability assessment (LCSA) a framework was established taking into account all three dimensions of sustainability, which is essential to display all resulting effects on sustainable development in a holistic way (Hacking and Guthrie, 2008). LCSA has also been promoted by the UNEP/SETAC life cycle initiative as a feasible framework to measure impacts on the three sustainability dimensions (UNEP, 2012; Valdivia et al., 2012). Within the following subsection the development and concept of life cycle sustainability assessment will be examined by pointing out the advantages and remaining challenges, which serves as a basis for the subsequent sections.

1.1. Life cycle sustainability assessment

The evolution of the LCSA framework has somehow been initiated with the development of the “Product Portfolio Analysis” (PROSA; German: Produktlinienanalyse) (Grießhammer et al., 2007; Öko-Institut, 1987). The PROSA approach was the first one considering three sustainability dimensions instead of one and can be seen as one of the initial ideas leading towards LCSA (Finkbeiner et al., 2010; Klöpffer, 2008). In addition, in the middle of the nineties the social and environmental life cycle assessment (SELCA) approach (O'Brien et al., 1996) was introduced referring to the three ring model similar to the one, which was later used within the LCSA framework. The current LCSA framework is still based on the three dimensions of sustainability economy, environment, and society and therefore takes up the structure of SD to a great extent (Giddings et al., 2002; Singh et al., 2012). It follows the triple bottom line of sustainability (Elkington, 1998) by integrating life cycle assessment (LCA) (Finkbeiner et al., 2006) to represent the environmental dimension, life cycle costing (LCC) to represent the economic dimension (Hunkeler et al., 2008) and social life cycle assessment (SLCA) to represent the social dimension (Benoit and Mazijn, 2009). Therefore, LCSA is clearly life cycle based (Klöpffer, 2008). Consequently, the three integrated methods LCA, LCC and SLCA have a similar modelling structure, following the life cycle of a certain product. The Guidelines of SLCA even state to follow the structure provided by ISO 14044, (2006) (Benoit and Mazijn, 2009). According to Swarr et al. (2011) similar accounts for LCC. Mainly this common ground was stressed to facilitate the definition and application of consistent system boundaries and functional unit for the three dimensions. However, the three methods have different target functions, which means they are looking at the same system from different perspectives (Heijungs et al., 2010; Wood and Hertwich, 2012).

The (theoretically) resulting advantage of LCSA is transparency, as it allows to identify trade-offs between the social, environmental and economic dimension (Heijungs et al., 2010). It is also often described as the most developed approach in terms of sustainability assessment (Zamagni et al., 2013). However, shortcomings exist, as LCA, LCC and SLCA do not have the same level of maturity, which hinders the broad implementation of LCSA. This is mainly substantiated by the evolutionary stage of the methods. Whereas, LCA is already a standardized method (ISO 14044, 2006) and widely used to investigate the potential environmental impacts of products and processes (Klöpffer and Grahl, 2014), LCC and SLCA are lacking of consensus and definition and thus broad practical implementation. SLCA assesses the potential social impacts of products and relates to the different stakeholder groups affected by the products, like workers, local communities and consumers (Benoit and Mazijn, 2009), but lacks proper impact assessment. LCC takes into account different perspectives (e.g. producer or consumer perspective) in order to consider the complete life cycle of a product (Hunkeler et al., 2008; Wood and Hertwich, 2012), but no impact level has been defined yet.

For LCA already broad range of well-described impact indicators is available and a common structure orientating on cause-effect chains has been developed (e.g. by the CML (Guinée, 2002) or ReCiPe (Goedkoop et al., 2009) method). Furthermore, related databases have already been established, e.g. GaBi or ecoinvent (UNEP and SETAC, 2011).

In comparison, for SLCA several impact categories have been proposed (Benoit and Mazijn, 2009; Neugebauer et al., 2014; Weidema, 2006), but they are still under discussion, as related impact pathways are lacking and the focus has so far been on the representation of stakeholder groups without bridging the gap towards impact assessment (Neugebauer et al., 2014). In addition, social data are hard to gather. Existing databases are only available on a top-down country or sector level, e.g. the Social Hotspot Database[1] (SHDB, 2013).

For LCC, similar to LCA it is possible to identify economic hotspots, which can be valuable for the decision making process within LCSA (Jeswani et al., 2010). Practical application is however lacking due to inconsistent documentation of cost sources (Wood and Hertwich, 2012) and poor data quality (Gluch and Baumann, 2004), even though some authors stated earlier that LCC is on a relatively fast track towards a comprehensive implementation

[1] The SHDB displays risk factors instead of impacts, but it is so far the only available database directly associated to SLCA.