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Substituting local data for overseas life cycle inventories – a case study of concrete products in Hong Kong

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ABSTRACT

Life cycle assessment has been widely adopted to evaluate the environmental impacts of a product. In many cases, a local life cycle inventory (LCI) is not available and the substitution of overseas LCIs by local data has become a common practice. Although substituting local data into existing LCIs is considered as an efficient way to create a 'partially localized' inventory, little has been known on the consequences of such adjustments, not to mention about the availability of a standard governing this issue. This study investigates the changes caused by replacing overseas LCIs with local data and provides suggestions based on a case study of concrete production in Hong Kong. Two existing overseas LCI datasets are used, namely Ecoinvent and US PCA. Thirty localized scenarios are performed at three different levels and the localized scenarios are compared with the two original datasets. The results indicate that the change of single score increases with the adjustments in the original LCIs. It is found that the substitution of local data into US PCA and Ecoinvent would yield different changes, despite the same adjustments are performed. The changes in the localized concrete datasets are mainly attributed to the adjustments of cement and transportation. Based on the research findings, it is suggested to examine the changes due to the data substitution and define the levels of adjustment. The percentage of adjustment should also be specified. The research findings of this study shall pave a way for the standardization of the adaptation of overseas LCIs in the future.

1. Introduction

1.1. Environmental impacts of concrete

Concrete being one of the most commonly used construction materials has been consumed at a rate of around 1 ton per person per year (Flower and Sanjayan, 2007). Hong Kong being an economic hub and metropolitan city has a huge demand for construction facilities. The annual concrete consumption per capita in Hong Kong is four times the world average (Tsang, 2009).

Concrete is a material which can cause significant environmental pollution. Cement as a key ingredient for the manufacturing of concrete contributes to about 5–7% of the world's carbon emission (Meyer, 2009). The carbon emitted from cement is mainly arising from pyroprocessing when clinker is produced (Josa et al., 2007, 2004). According to Flower and Sanjayan (2007) and Habert and Roussel (2009), the energy required for pyroprocessing would generate 0.7–1.0 kg of carbon dioxide per kg of cement, while around 0.5 kg of carbon dioxide could be released from calcination and the rest is from fuel combustion.

Acknowledging the huge environmental impact brought by concrete, increasing attention has been attributed to the greenness of concrete in particular its carbon footprint, energy consumption, particulate matter emission, toxicity, resource depletion, etc. Researchers have been attempting to apply a life cycle assessment (LCA) approach to model the environmental impacts of concrete. For example, Sjunnesson (2005) examined the carbon emissions through the life cycle chain of concrete. Huntzinger and Eatmon (2009) investigated the improvement in environmental performance signified by various impact categories when cementitious materials are used to adjust the clinker content in cement. The opportunity of reducing the environmental impacts by using high performance concrete was also explored by Habert et al. (2012) while the pollution caused by cement production in China was estimated through LCA (Li et al., 2014).

1.2. Adjustment of life cycle inventory

LCA (ISO, 2006a, b) is a widely adopted method to evaluate the life cycle environmental impacts of a product from its

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manufacturing and usage to the end-of-life disposal. Of various critical procedures in LCA, establishing a life cycle inventory (LCI) of the studied product is essential. LCI strives to document the energy, material and emission flows in order to represent the relationship between the unit processes as well as their impacts to the environment. An ideal LCI should be based entirely on site-specific data solicited from relevant stakeholders. Despite that, as a product's life cycle is composed of hundreds and thousands of unit processes, collecting all the necessary site-specific data would consume considerable time and cost rendering it unrealistic to obtain such data (Moreau et al., 2012).

A more pragmatic alternative is to rely on the country-specific data as it reflects the average condition of a certain product in a country. However, not all countries/cities maintain this type of data with Hong Kong being an example. The reliance on overseas LCI data is hence inevitable and becomes a common practice. For instance, Zhao (2009) studied the solid waste treatment systems in China using the Ecoinvent database with most of the data originated from Europe. On the other hand, Luo et al. (2009) estimated the environmental impacts of bioethanol by acquiring data from published reports and overseas LCI databases. In Hong Kong, an LCA/LCC software tool was developed for commercial buildings primarily following an LCI database namely IVAM (EMSD, 2006). However, significant discrepancy can be observed between different LCI sources (Josa et al., 2004; Maurice et al., 2000). It has been reported that the datasets from distinctive LCI sources are different in certain aspects especially in terms of their boundary definition, data format, level of documentation, etc. (Suh et al., 2013). Inappropriate usage of overseas data may lead to problems like double counting and misinterpretation (Van den Heede and De Belie, 2012) not to mention about errors in analysis (Hong et al., 2013).

To better reflect the reality, adaptation of foreign LCI data should be performed to replace certain processes or parameters with first-hand data obtained from the local industry. For example, Nebel et al. (2011) formulated the LCIs for construction materials in New Zealand by integrating local data into the GaBi's database. Similarly, the Hong Kong Housing Authority has established an inventory of construction materials based on overseas databases like IVAM, BUWAL and ETH-ESU (HKHA, 2005). Colodel (2008) put forward an approach to transfer the LCI data between countries by providing a set of conversion factors. Chau et al. (2007) developed a process flow chart to help identify the possible adjustments for the LCIs of construction materials. In general, what variables should be adjusted is determined by the availability of local data, with electricity mix, fuel and transportation being the most common variables for the adjustment as demonstrated in previous studies. Nonetheless, substitution of local data for overseas LCIs may change the results significantly. More importantly, different levels of adjustment can affect the interpretations of the studied product. Although replacing the overseas LCIs with local data is an efficient way for regions without any country-specific LCIs, there is no standard governing how to adjust the LCI. Besides, the effects on the results caused by the adjustment of LCI have not been fully examined.

1.3. Aim and objectives

To bridge the research gap, this study aims to investigate the consequences of substituting site-specific data into the existing overseas LCIs and provide suggestions on how to perform the adjustment to overseas LCI datasets based on a case study of concrete in Hong Kong. Before creating a new dataset using the existing LCIs, it is necessary to understand the differences between these LCIs and explore the underlying rationales behind such divergences. As a result, this study compares the available LCIs of concrete by looking into their model setups and impact assessment results. The adjustment of overseas LCIs is performed to combine the local data of concrete production with the existing datasets. The influence brought by the LCI adjustment is examined by comparing the impact assessment results of the localized datasets with those of the original.

A review of previous research studies shows that there is no agreed method to substitute local data into existing LCIs. This study, therefore, strives to improve our understanding on the influence caused by the adaptation of existing LCIs according to the local context. The methods of LCI adjustment are further discussed in light of the case study of concrete in Hong Kong as well as the relevant previous studies. The research findings may pave way for standardizing the LCI adjustment in future.

2. Research design

As shown in Fig. 1, this study consisted of five stages. The first stage strived to investigate the current situation of LCI adjustment by using the local data and to identify the relevant research problems.

In the second stage, the existing LCI data sources were reviewed and those with a more comprehensive set of inventories for concrete were selected for the purpose of substituting local data into the overseas LCI. The chosen datasets were compared both qualitatively and quantitatively to delineate their differences in terms of elementary flows, model structure and impact assessment results.

While it is necessary to determine what processes should be adjusted before data is collected, the third stage intended to identify what are the possible adjustments through a review on published papers and reports. Based on that, the necessary local concrete data was collected to facilitate the adjustments. Acknowledging the complexity of data required, site visits to concrete batching plants in Hong Kong were arranged to record and collect the necessary data.

In the fourth stage, the LCI was adjusted by progressively replacing certain variables in the original LCIs with local concrete production data. Totally, 30 localized scenarios were performed at three levels. The adjusted LCI datasets were further compared with the original datasets in terms of their impact assessment results. An LCA software SimaPro 7 (Consultants, 2006) was employed to establish the LCIs and generate the impact assessment results. The

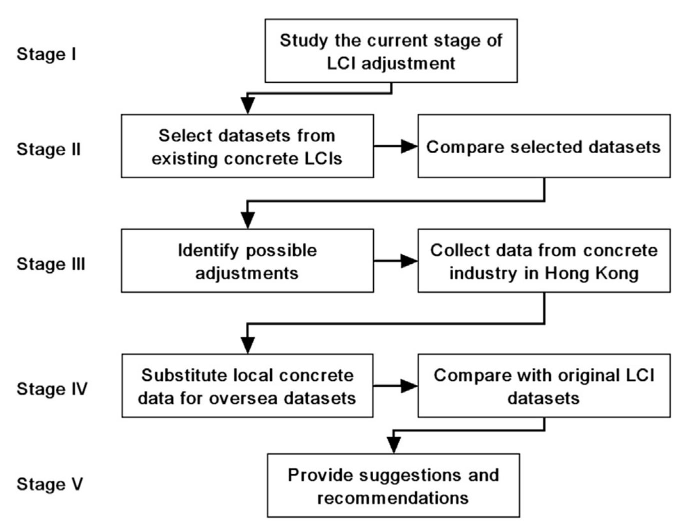

Fig. 1. Flow chart to illustrate the research design.