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Review

Application of life cycle thinking towards sustainable cities: A review

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ABSTRACT

Defining sustainable cities is not straightforward. The main issues involved in urban sustainability are buildings, energy, food, green areas and landscape, mobility, urban planning, water and waste; and their improvement is promoted through different strategies. However, a quantitative method, such as life cycle thinking (LCT), is essential to evaluating these strategies. This paper reviews LCT studies related to urban issues to identify the main research gaps in the evaluation of these improvement strategies. The review identifies the main sustainability strategies associated with each urban issue and compiles articles that deal with these strategies through LCT, including environmental life cycle assessment (LCA), life cycle costing (LCC), social LCA (S-LCA) and life cycle sustainability assessment (LCSA), as well as integrated analyses with combined tools. Water, waste and buildings are the urban issues that accounted for a larger amount of studies. In contrast, a limited number of papers assessed urban planning and energy (excluding energy in buildings). Strong interrelations among urban issues were identified, most of them including water. In terms of methods, 79% of the studies exclusively applied life cycle tools (i.e., LCA, LCC, S-LCA or LCSA). Within this group, the environmental dimension was the focus of 84% of the papers. Single environmental indicators (e.g., global warming) were common in 20% of the analyses, highlighting the need to integrate more impact categories to prevent trade-offs. In the field of social and sustainability assessment, there is a need for methodological advances that foster their application in urban areas. Further research should cover the thematic and methodological gaps identified in this paper, such as developing models that assess complex urban issues, generating comprehensive LCT studies and promoting multi-indicators. Life cycle tools might benefit from revising the methodology with stakeholders to optimize the understanding and communication of life cycle results for policy- and decision-making processes.

Contents

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1. Introduction

Sustainability is key to ensuring good living standards in cities without compromising the environment, economy and society, especially considering that already 50% of the world's population lives in urban areas (UN, 2012). Cities are the result of combining technical, cultural, institutional, economic and psychological systems (Allenby, 2009) and their integrated management is complex. In terms of environmental performance, it is widely recognized that cities are the source of a number of environmental impacts, such as climate change (Kennedy et al., 2012), contributing to 70% of the global greenhouse gas emissions (GHG) (UN-HABITAT, 2011). However, there are other sectors outside the city boundaries, such as agriculture or power generation, that are linked to the growth of cities and also contribute to the global environmental performance of citizens (Satterthwaite, 2008). Additionally, urban sustainability also faces social justice issues (Harvey, 2009) while promoting the development of local economies. The question is: what is a sustainable city and which are the strategies that foster sustainable cities?

There are many issues involved in the daily metabolism of a city, e.g., food, energy, water, transportation, etc. In this paper, we identify the issues included in urban management, which are thus essential to defining future sustainable cities. Within these issues, we study the strategies promoted by reference institutions for improving their performance. In the framework of life cycle thinking (LCT), we discuss how these strategies were covered in the literature to determine their implementation potential at an urban scale.

1.1. Defining a sustainable city

A consensual definition of sustainable cities does not exist, although most organizations share the same viewpoint. The Institute for Sustainable Communities (2017) published a concise proposal based on the Sustainable Communities Task Force Report (President's Council on Sustainable Development, 1998): "*A sustainable community is one that is economically, environmentally, and socially healthy and resilient. It meets challenges through integrated solutions rather than through fragmented approaches that meet one of those goals at the expense of the others*". This definition calls for an integration of the policies and strategies aimed at improving the sustainability of key urban issues. However, these are typically dealt with independently to solve specific problems, such as the access to public transport or waste management. To identify the strategies proposed for each urban issue in the development of sustainable cities, we screened a set of fifteen reports and data from international organizations. Subsequently, we identified 28 potential improvement strategies (Table 1) that refer to 8 urban issues, namely buildings, energy, food, green spaces and landscape, mobility, urban planning, waste and water. In general, most strategies point to an increased process efficiency, the implementation of greener materials/designs and the integration of new technologies into the existing pool of alternatives.

1.2. Life cycle thinking (LCT) applied at the city scale

The feasibility of each strategy in environmental, economic and social terms is key to ensuring a sustainable urban performance. Quantitative studies can help to conduct this assessment, and LCT might be a suitable tool. According to the UNEP/SETAC Life Cycle Initiative (2017), LCT is "*about going beyond the traditional focus on production site and manufacturing processes to include environmental, social and economic impacts of a product over its entire life cycle*". This approach can be applied at different scales that range from single products to more complex systems, such as cities. Within this framework, four methods were developed to quantify the dimensions of sustainability. Life cycle assessment (LCA) (ISO 14040:2006) and life cycle costing (LCC) (ISO 15686-5:2008) quantify the environmental and economic impacts of a product system from raw material procurement to end of life, respectively. Social LCA (S-LCA) and life cycle sustainability assessment (LSCA) are newer methods (UNEP-SETAC, 2011, 2009), but their application is still incipient and needs standardization. LCT is the core of several policy action plans, including ecolabels and eco-innovation strategies (European Commission, 2010a). Indeed, as stated in previous literature the development of a comprehensive methodology for the implementation of LCSA is still lacking, and issues regarding indicators, weighting and trade-offs between validity and applicability must be addressed (Finkbeiner et al., 2010; Guinée et al., 2011). S-LCA needs further development, facing major challenges with regard to representation of results and data quality, among others (Macombe et al., 2013).

As defined in Section 1.1, strategies implemented to achieve sustainable cities should not work against each other. In this sense, LCT can provide integrated results for decision-making. However, LCT has been applied differently to the various issues involved in urban metabolism, leading to unbalanced data availability for evaluating sustainable strategies. Although the methodological limitations of LCT are well-known among practitioners, there is a