Journal of Environmental Management xxx (2016) 1–14

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Review

Sustainable infrastructure: A review and a research agenda

Antônio Márcio Tavares Thomé [a, *], Paula Santos Ceryno [b], Annibal Scavarda [b], Arne Remmen [c]

[a] Industrial Engineering Department, Pontifical Catholic University of Rio de Janeiro, Rua Marquês de São Vicente, 225 Sala: 950L, 22453-900, Rio de Janeiro, RJ, Brazil
[b] Production Engineering School, Federal University of the State of Rio de Janeiro, Avenida Pasteur, 458, 22290-240, Urca, Rio de Janeiro, RJ, Brazil
[c] The Faculty of Engineering and Science, Department of Development and Planning, Center for Design, Innovation and Sustainable Transitions, Aalborg University, Skibbrogade 5, 9000 Aalborg, Denmark

ARTICLE INFO

Article history:
Received 11 December 2015
Received in revised form
20 September 2016
Accepted 25 September 2016
Available online xxx

Keywords:
Sustainable infrastructure
Systematic literature review
Research agenda
Taxonomy
Green infrastructure
Sustainable building

ABSTRACT

This paper proposes a taxonomy of themes and a research agenda on sustainable infrastructure, with a focus on sustainable buildings (SB) and green infrastructure (GI). The citation databases of Web of Science formed the basis for a novel strategic thematic analysis of co-citation and co-occurrence of keywords with a longitudinal identification of themes during the last two decades (from 1995 to 2015) of an emerging and ever growing research area. SI is a multidisciplinary endeavour, including a diversified array of disciplines as general engineering, environmental ecology, construction, architecture, urban planning, and geography. This paper traces that the number of publications in SI is growing exponentially since 2003. Over 80% of total citations are concentrated in less than 10% of papers spread over a large number of journals. Most publications originate from the United States, Europe, Australia, and Asia. The main research streams in SI are green infrastructure, sustainable buildings, and assessment methods. Emerging and prevailing research themes include methodological issues of cost-effectiveness, project management and assessment tools. Substantive issues complement the research agenda of emerging themes in the areas of integration of human, economic and corporate social responsibility values in environmental sustainability, urban landscape and sustainable drainage systems, interdisciplinary research in green material, integrated policy research in urbanization, agriculture and nature conservation, and extensions of Green Building (GB) and GI to cities of developing countries.

Contents

* Corresponding author.
E-mail addresses: mt@puc-rio.br (A.M.T. Thomé), paulaceryno@hotmail.com (P.S. Ceryno), annibal.scavarda@unirio.br (A. Scavarda), ar@plan.aau.dk (A. Remmen).

http://dx.doi.org/10.1016/j.jenvman.2016.09.080
0301-4797/

1. Introduction

Since the first attempts to assess infrastructure's environmental impact in the late 1980's, the sustainable infrastructure (SI) field has gradually been broadening its scope from green building (GB) to green infrastructure (GI) and from environmental sustainability (ES) to the triple bottom line (TBL) of economic, social, and environmental sustainability (Ferrer et al., 2016). The term environment means in this paper "surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans, and their interrelationships" (ISO, 2015). GI is "a patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water;" it relates mainly to the "storm water management systems that mimic nature soak up and store water" (Fiksel et al., 2012). Sustainable development as stated in the Brundtland report is "… development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987).

Although green building (GB) and green infrastructure (GI) are often interchangeably related to SI topics (e.g. Kevern, 2011; Naumann et al., 2011), they carry different meanings. Kibert (2016) defined green buildings as "… healthy facilities designed and built in a resource-efficient manner, using ecologically based principles." GI is defined "… as planned and managed natural and semi natural systems that provide products and services with environmental, social, economic, and/or health benefits" (Dimuro et al., 2014). Sustainable infrastructure (SI) supports the buildings, engineering works, and infrastructure that are essential for the society survival (Boyle et al., 2010). Consequently, SI topics are of the upmost relevance for the wellbeing of people, the economy and the earth, which includes considerations about natural hazards (Padgett et al., 2009).

SI research can currently be ascertained by the large number of literature reviews in the subject, appearing in citation databases. A query in the titles, abstract, and keywords of Web of Science (WoS) database with the search keywords "sustainab* infrastructure" OR "sustainab* construction" OR "sustainab* building" OR "green construction" OR "green building" OR "green infrastructure, " after restricting to English language titles and setting type of documents to review only, resulted in the retrieval of 122 reviews. This result attests the vigor and relevance of the field. Narrowing the analysis to contemporary reviews appearing after 2013, the most prominent themes outlined in broad categories include energy (e.g., Pombo et al., 2016; Yu and Su, 2015; Hong et al., 2015; Fumo, 2014; Pietrosemoli and Rodríguez Monroy, 2013), built materials (e.g., Oyelami and Van Rooy, 2016,; Govindan et al., 2015; Achal and Mukherjee, 2015; Bories et al., 2014; Memon, 2014; Madurwar et al., 2013), evaluation and assessment tools (e.g., Wu et al., 2016; Suzer, 2015; Pushkar and Shaviv, 2014, 2014; Alyami et al., 2013; Pushkar and Shaviv, 2014; Alyami et al., 2013), emissions (e.g., Wang et al., 2014a), water system (e.g., Ma et al., 2015; Rashidi et al., 2015), and ecosystems services (e.g., Salmond et al., 2016; Ziter, 2015). In a literature review focusing predominantly on environmental issues related to water and sustainability, Zhou et al. (2013) proposed a similar taxonomy in broad categories of SI topics published in 2012 in peer reviewed journals and conferences. The categories were sustainable water, wastewater utilities and treatment, sustainable water resources management, industrial and corporate approaches to sustainability, storm water and green infrastructure, energy in wastewater industry, climate change and water reuse, life cycle assessment applications, and sustainability rating systems.

Although several recent reviews have covered specific topics related to SI, none provides a general overview of main themes and a longitudinal analysis of how they have evolved in the recent past, as intended in the present review. This longitudinal approach differs from previous literature reviews in two important ways. The scope is broader and intended to depict the landscape of research in SI, rather than to focus on a specific topic or subtheme. It retraces the evolution of themes in time, in a dynamic analysis showing the progression of main SI research streams.

The purpose of this paper is to provide a general overview of the research themes in the area of SI and to portray its evolution in time, with the objective of answering three specific research questions (RQs). First, which are the main themes in the area of sustainable infrastructure? Second, are the themes stable in time, and if not, how have they evolved? Third, what are the emerging themes and the future research directions in sustainable infrastructure?

The structure of the paper is as follows. After this introduction, there is a description of the materials and methods of the systematic literature review and bibliometric analysis. The presentation of results of the co-citation and co-word analysis ensues and describes a longitudinal taxonomy of themes. The discussion of main findings and the research agenda conclude the paper.

2. Research methods

Basic bibliometric analysis are combined with co-citation and co-word analysis in an objective and transparent manner following the procedures outlined in Thomé et al. (2015, 2016). The next subsections describe the methods of the systematic literature review, citation, co-citation, and co-word analysis.

2.1. Systematic literature review

A seven-step approach based on Cooper (2010) is adapted to conduct the systematic literature review, following the guidelines contained in Thomé et al. (2016). The first step is the planning and formulation of the problem. A research team was instituted from the onset and the team comprises the co-authors of this paper. The co-authors discussed the conceptualization of sustainable infrastructure, they formulated the research questions, and they defined the research expected outcomes: the taxonomy of themes, the description of their evolution in the past 20 years, and the future research directions. The second step is the search strategy definition, which includes selection of computerized databases, search keywords, criteria to include or to exclude papers in the review, coders' training, and assessment and discussion of disagreements among reviewers.

The approach to search and to select studies was based on von Brocke et al. (2009) and Thomé et al. (2012, 2014). The Thomson Reuters' Web of Science™ (WoS) database was selected. The Scopus citation database could be selected as well and should provide similar results in the scientific field of natural sciences and engineering (NES) (Mongeon and Paul-Hus, 2016). WoS was preferred over the Scopus citation database due to the following reasons. First, despite a larger coverage of journals in Scopus citation database overall, WoS has a larger number of unique journal titles in NES (Mongeon and Paul-Hus, 2016). Second, it offers a more thorough coverage of older literature (Hlwik, 2016). Finally, the Histcite™ software interact directly with WoS and eases the analysis of citation networks, as applied in this paper.

The third and fourth steps are data gathering and quality evaluation. The WoS database was exported to Histcite™ for basic statistics and bibliometric analysis. The fifth and sixth steps of the protocol adopted for this systematic literature review are data analysis and interpretation. The seventh is the result presentation (Thomé et al., 2016). Data analysis followed an inductive approach (Seuring and Müller, 2008). Basic statistics on publication years,

Please cite this article in press as: Thomé, A.M.T., et al., Sustainable infrastructure: A review and a research agenda, Journal of Environmental Management (2016), http://dx.doi.org/10.1016/j.jenvman.2016.09.080