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Sustainable urban infrastructure: A review

Ana Luiza Carvalho Ferrer[a], Antônio Márcio Tavares Thomé[a,*], Annibal José Scavarda[b]

[a] Industrial Engineering Department, Pontifícia Universidade Católica do Rio de Janeiro Rua Marquês de São Vicente, 225 sala: 952.22453-900, 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

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ABSTRACT

Urban infrastructure is a multifaceted concept that goes beyond a set of engineered facilities, utilities, and systems. It is equally a place for local and global governance, intertwining issues of economic growth, climate change, and municipal waste. The concept of sustainability is relatively new and it encompasses a multidisciplinary field made of engineering, economic, social, and environmental sciences. Research in sustainable urban infrastructure is a new and ever evolving field.

This paper offers a verifiable and reproducible systematic literature review of sustainable urban infrastructure, electronically analysing and scrutinizing 995 papers for the co-occurrence of keywords. It aims to answer two research questions: (i) what are the sustainable urban infrastructure prevailing themes and (ii) how have these themes evolved? The main themes identified were storm-water, developing countries, cities, investments, urban areas, environmental impact, life cycle, climate change, urban infrastructure, and vulnerability. Sustainable urban infrastructure themes have evolved from modernity in urbanism, slum areas, and degradation of urban spaces in the mid of last century to ecological views of the built environment and urban networks. The taxonomy of themes and the analysis of its evolution led to a research agenda on disaster mitigation, maintenance and sustainability of facilities and utilities, urban metabolism and vulnerabilities, e-city, and communication networks.

1. Introduction

Nowadays the majority of the world population lives in cities, for the first time in human history, and 66% of this population might live in urban areas by 2050 (United Nations, 2014). About 80% of the total greenhouse gas (GHG) emissions come from cities, with 25% attributed to urban transportation, 32% to urban built environment, and an additional 5% to municipal solid waste. Urban transportation accounts approximately 20% for the global energy consumption and urban built environment responds to an additional 25% (Martos et al., 2016). Climate change and the additional burden it imposes on the economy, life of the population, and environment aggravate concerns of sustainable urban infrastructure (SUI), including deleterious effects in urban water management (Pingale et al., 2013), urban heat island effects (Kleerekoper et al., 2012), pavement production, and construction (White et al., 2010).

Urban infrastructure (UI), by itself, is a multifaceted concept that goes beyond a set of engineered facilities, utilities, and systems. It is equally a place for local governance, intertwining issues of economic growth, climate change, and municipal waste. There are different levels to tackle the UI issues as well, from supranational institutions to national, regional, and local governments. The UI functioning affects regulators, consumers, citizens, businesses, and households alike (Hodson and Marvin, 2010). From an engineering perspective, it refers to engineered systems that provide water, energy, transport, sanitation, information, built environment, and irrigation systems (e.g. dams, locks, and canals). It also covers facilities (e.g. schools or hospitals), and municipal utilities (e.g. electric, telecommunication, gas, water, and wastewater along with urban street and highway elements) (El-Diraby and Osman, 2011). In this sense, the urban space is a place for extreme pressure and for political and economic power too.

The sustainability concept is relatively new and it encompasses a multidisciplinary field made of engineering, economic, social, and environmental, sciences (El-Diraby and Osman, 2011). Sustainability in the definition of the Brundtland Commission is the ability to meet the needs of the present generation without compromising the chances of the future generations to fulfil their own needs (WCED, 1987; Birkin et al., 2009). Under the triple bottom line (TBL) approach, sustainability encompasses economic, social, and environmental concerns (Elkington, 1994).

* Corresponding author.
E-mail addresses: analcferrer@gmail.com (A.L.C. Ferrer), mt@puc-rio.br (A.M.T. Thomé), annibal.scavarda@unirio.br (A.J. Scavarda).

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Table 1
The papers selected for review.

Search keywords	No. of papers included
"urban infrastructure" AND "green"	258
"urban infrastructure" AND ("green" OR "sustainab*")	645
"urban infrastructure" AND ("green" OR "sustainab*OR "environment*")	1180
Exclusion criteria	
Restricted to articles, conference papers, reviews, and articles in press	1059
English language only	995

Table 2
The top SUI subject areas.

Scopus categories	No. of papers
Social science	367
Environmental science	346
Engineering	294
Earth and planetary sciences	130
Computer science	114
Agricultural and biological sciences	75
Business, management, and accounting	71
Energy	49
Medicine	39

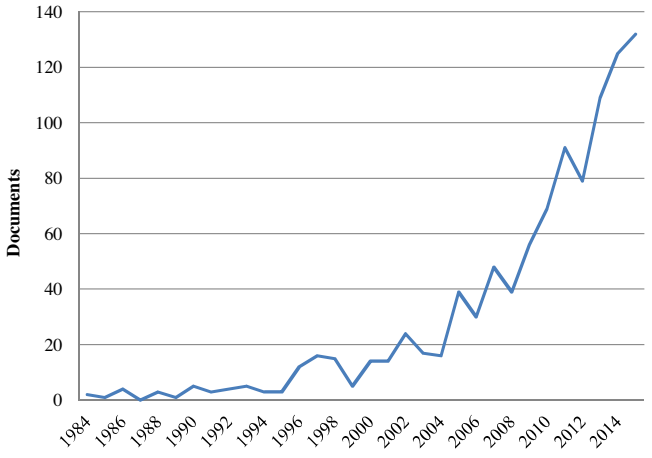

Fig. 1. The number of the SUI papers per year.

Sustainability is an all-inclusive concept designating a process of achieving human development over time and space, embracing the interdependencies of the ecology with economic and social aspects, in an equitable and safe manner that requires technological, scientific, and political discernment (Gladwin et al., 1995; Adams et al., 2012). In this context and borrowing from Martos et al. (2016, p. 480), "a sustainable resource efficient city can be defined as a city that is significantly decoupled from resource exploitation and ecological impacts and that is socio-economically and ecologically sustainable in the long term."

The SUI multidisciplinary and multi-layered concept evolved over time. This paper aims to disentangle the prevailing themes pursued under SUI and to respond two basic research questions (RQ):

RQ1–What are the prevailing themes in sustainable urban infrastructure?

and

RQ2–How have the themes of sustainable urban infrastructure evolved?

The study comprises this introduction, followed by the description of the methodology of the literature review and basic statistics. Results from citation, co-citation, and co-word analyses ensue. Conclusions close the paper.

2. Methodology

This section comprises the methods and basic statistics from the systematic literature review (SLR) and methods applied to the longitudinal analysis of the thematic areas.

2.1. The systematic literature review and basic statistics

A SLR was conducted using the Thomé et al.'s (2016) step-by-step approach. This approach, based on Cooper (2010), consists of eight basic steps: (i) planning and formulating the problem, (ii) searching the literature, (iii) data gathering, (iv) quality evaluation, (v) data analysis and synthesis, (vi) interpretation, (vii) presenting results, and (viii) updating the review.

For the first step, the co-authors of this paper gathered to clarify and discuss the SUI concept, defining the research questions and expected research results. This step anticipated the attainment of a taxonomy of themes, an understanding of their evolution over the past years, and possible impending areas of this study.

The second step comprised selecting databases, defining search keywords, and applying exclusion criteria for papers, with no time restrictions. Elsevier's Scopus database was selected for its vast abstract and citation collection of over 22,000 journals (HLWIKI Canada, 2015). The search keywords applied to Scopus and the exclusion criteria are in Table 1.

At first the search keywords were "urban infrastructure" and "green," yielding 258 papers. Next the keywords "sustainab*" (referring to the keywords produced by the combination of the root "sustainab" and any suffix) were added, resulting in 645 papers. The inclusion of the keywords "environment*" expanded the selection to 1180 papers. The limitation of the search based on document type (articles, conference papers, reviews, and articles in press) refined the search to 1059 papers. Moreover, the exclusion of the papers published in languages other than English narrowed the selection to a final set of 995 papers. The full bibliographic reference is available upon request to the corresponding author.

For the third and fourth steps, the co-authors of this paper used basic statistics on the selected papers with Scopus' built-in bibliometric software that provides basic statistics on issues like research subject areas, publications per year, journals, institutions, citations, and h-index per authors. The h-index definition is simply the number of papers with citation number $\leq$ h and it is a measure of the influence of a publication, a journal, or an author in the research field (Hirsch, 2005). Table 2 depicts the top SUI subject areas, which have not surprisingly spread over several research fields, denoting the SUI eminent multi-disciplinary nature.

With 367 and 346 papers respectively social science and environmental science have clearly been the most common subject areas with roughly one third of all papers each. It is also worth to mention other areas: engineering with 294 papers, earth and planetary sciences with 130 papers, and computer science with 114 papers. The top recurring subject areas have also included agricultural and biological sciences; business, management, and accounting; energy; and medicine. The prominence of publications from the social and environmental sciences reflects on the co-citation analysis and in the approaches to SUI adopted by the most cited authors analysed in Section 3.2.

Fig. 1 illustrates the number of the SUI papers published per year. The first published paper dated back to 1984 and until 1995 there was a yearly average of three papers. A sudden increase occurred after 1996. Since 1999 the number of documents published has had

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