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Environmental sustainability benchmarking of the U.S. and Canada metropoles: An expert judgment-based multi-criteria decision making approach

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ABSTRACT

In this paper, environmental sustainability performance assessment of 27 U.S. and Canada metropoles is addressed. A four-step hierarchical fuzzy multi-criteria decision-making approach is developed. In the first step, the proposed methodology is established by determining the sustainability performance indicators (a total of 16 sustainability indicators are considered), collecting the data and contacting experts from academia, U.S. government agencies and within the industry. In the second step, experts are contacted and the entire list is finalized; sustainability performance evaluation forms are delivered; and then expert judgment results are obtained and quantified, respectively. In the third step, the proposed Multi-criteria Intuitionistic Fuzzy Decision Making model is developed and sustainability performance scores are quantified by using the collected data, multi-criteria decision making model and sustainability indicator weights obtained from expert judgment phase. In the final step, the sustainability scores and rankings of the 27 metropoles, results analysis and discussions, and statistical highlights about the research findings are provided. Results indicated that the average sustainability performance score is found to be 0.524 over scale between 0 and 1. The metropole with the greatest sustainability performance score is found to be New York with 0.703 and the poorest performing city is identified as Cleveland with 0.394. The results of the statistical analysis indicate that the greatest significant correlations are obtained with carbon dioxide (CO_2) emissions per person (−0.749 – significant negative correlation with sustainability performance score) and share of workers traveling by public transport (+0.753 – significant positive correlation with sustainability performance score). Therefore, the CO_2 emissions and public transport are found to have the most significant impact on the sustainability scores.

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Introduction

Sustainable development

In 1983, sustainable development was first initiated as an environmentally friendly, economically feasible and socially acceptable growth philosophy in the Brundtland Commission, which was formally named as the World Commission on Environment and Development (WCED). Sustainable development was defined as "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). Today, sustainable development initiatives are becoming more crucial due to considerably high deteriorating effects of industrial and service activities on the earth's carrying capacity (Egilmez & Park, 2014; Egilmez & Tatari, 2011). In this regard, it is critical to evaluate the environmental burdens to make policies toward realizing the objectives of sustainable development. Specifically, environmental impact categories, including greenhouse gas (GHG) emissions, energy consumption, toxic releases, water withdrawals and hazardous waste generation have become cornerstones of any environmental impact assessment study in sustainability research (Bevilacqua, Ciarapica, & Giacchetta, 2012; Egilmez, Kucukvar, & Tatari, 2013; Egilmez, Kucukvar, Tatari, & Bhutta, 2014; Kucukvar & Tatari, 2013).

On the importance of metropoles

Among the important focus areas for a sustainable future; governments, politicians, social actors and all the stakeholders that are involved in broad long term decision making processes need

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to pay attention to various areas including growing metropoles to realize a successful sustainable development throughout the country. Because, today, metropoles are one of the significant drivers of the environmental pollutions in various impact categories such as natural resource consumption, waste generation, transport and air pollution. Several works discuss and provide statistical highlights about metropolitan areas' environmental impacts, which often indicate people that live in metropolitan areas have a significantly higher environmental footprint compared to ones that live in non-metropolitan areas (Owen, 2009). For instance, the average electricity use of a person living in a city is about twice as much as person who does not (Royte, 2009).

Sustainability indicators and benchmarking needs

Sustainability performance measurement is a very critical step in sustainability development planning. Indeed, sustainability performance indicators have attracted considerable attention worldwide, which needs to represent a reliable, long-term-focused, easily understandable proxy for broader areas of concern to sustainable development (Wheeler, 2000). Groups working toward developing a consensus on sustainability indicators for cities include Sustainable Seattle Coalition in the early 1990s, the Oregon Benchmarks initiated by the State of Oregon in the early 1990s, Bay Area Alliance for Sustainable Development and City of Toronto's Healthy City Program (Wheeler, 2000). All in all, these reports mainly recommend city-wide or regional sustainability projects to focus on resource consumption, waste generation, global warming effects, quality and health performance of transport and air, and other aspects of daily life. Among the sustainability performance indicator categories, energy and water consumption, air pollution and carbon dioxide (CO_2) emissions, recycling and waste generation, land and building footprints and transportation related sustainability performance can be considered as the main and widely addressed indicator categories, which are highlighted in various reports of government agencies, such as Environmental Protection Agency (EPA). Additionally, sustainability performance indicators also widely addressed in the literature (e.g., Bell & Morse, 2008; Mega & Pedersen, 1998; Devuyst, Hens, & De Lannoy, 2001) and in the projects completed for various cities, such as Minneapolis (City of Minneapolis Sustainability Report, 2012) and Santa Monica (Sustainable City Progress Report, 2012). These indicators are also matching with the needs for transitioning the cities to more resilient and sustainable alternatives that will work toward reaching the sustainable development of regional and global urban communities (Collier et al., 2013; Mori & Christodoulou, 2012; Pickett et al., 2013). Moreover, a complete sustainability understanding also necessitates the consideration of environmental and ecological indicators related to the use of natural resources in the cities and the regions along with the ones associated with the society and economy as a whole (Budd, Lovrich, Pierce, & Chamberlain, 2008; Ceccato & Lukyte, 2011). While sustainability indicators are developed for quantifying the sustainability performance of cities, it is important to compare metropoles from an overall sustainability performance viewpoint. However, sustainability indicators are typically considered from diverse fields including energy, water resources, air pollution and transport, and civil infrastructures, where indicatory categories are mostly represented with a different unit of measurement (Olewiler, 2006). Therefore, finding an overall sustainability performance score becomes a challenging task, which requires appropriate scientific approaches that can quantify the sustainability performance of different cities. In this regard, multi-criteria decision making (MCDM) approaches provide the flexibility and robustness to deal with the benchmarking problems where multiple and varying units of measurements exist. This paper utilizes an integrated fuzzy MCDM and expert judgment framework to analyze and compare the sustainability performance of 27 metropoles in the U.S. The rest of the paper is organized as follows. In the second section, literature review is provided. The third section introduces the proposed methodological framework. In the fourth section, results are presented. Section five introduces statistical highlights about the findings of the study. Finally, in section six, conclusions, discussion and future remarks are mentioned.

Background

Sustainability benchmarking for cities, regions, etc.

Sustainability benchmarking is a critical step toward realizing the sustainable development goals of different regions simultaneously. In this regard, quantitative assessment methods are of importance due to the well-known mantra derived from the business world, "*what gets measured gets managed*". However, problems and debates, naturally, arise when it comes to what types of and which indicators need to be included in sustainability benchmarking projects and to what extent a standardization is required (Moreno Pires, Fidélis, & Ramos, 2014; Ramos & Moreno Pires, 2013). Several sustainability indicator standardization initiatives have been taken place especially in Europe on local sustainable development indicators, such as "Making news for monitoring progress (1999)", "European Common Indicators, a.k.a. ECI (1999–2003)", Local Authorities' Self-Assessment Local Agenda 21, a.k.a. LASALA (1999–2002) and LASALA-ON-LINE (2003–04), Indicators to Assess New Urban Services, a.k.a. IANUS (2000–2003), A European Thematic Network on Construction and City Related Sustainability Indicators, a.k.a. CRISP (2000–03), and Indicators into Action: Local Sustainability Indicator Sets in Their Context, a.k.a. PASTILLE, (2000–02), etc. (please check Moreno Pires et al., 2014 for the full list). Even though there has been significant efforts made toward standardizing the sustainability indicators to be used for benchmarking purposes, there is still a lack of official consensus in Europe and many other regions in the world (Moreno Pires et al., 2014). One reason for the lack of consensus is due to the fact that the set of indicators to be used does vary depending on the objective of the study, local characteristics of the regions, cities, etc. However, all in all, it is still critical to provide quantitative decision support frameworks that can get benefit from experts' perspectives and real data associated with the triple-bottom-line (TBL) dimensions of the sustainability to improve the overall decision making.

Multi-criteria decision making (MCDM)

Multi-criteria decision making (MCDM) methods are associated with configuring and solving decision making problems involving multi-criteria and iterative decision making processes (Kucukvar, Gumus, Egilmez, & Tatari, 2014; Kucukvar, Noori, Egilmez, & Tatari, 2014). Mainly, two objectives can be considered as the scope of MCDM methods, namely: ranking and selection or alternatives. MCDM methods typically support the decision makers in iterative decision making processes, in which rigorous mathematical formulations are used. The fundamental advantage of MCDM is that these models make it possible to deal with a considerably large number of data, relations and objectives, which are the typical characteristics of a real-world policy problem (Munda, 2005). Real-world problems include such complexity where multi-dimensional parameters or factors often effect the decision making process for ranking or alternative selection. In this context, MCDM methods are used as robust approaches due to their wide applicability in the literature, such as planning (Hosseini Nasab & Milani, 2012), finance and economics (Lee, 2011; Wu, Tzeng, & Chen, 2009), management (Chai, Liu, & Ngai, 2013; Dursun & Karsak, 2010; Tseng, 2011), education (Chen