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Research article

Multi-criteria decision-making for sustainable metropolitan cities assessment

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ABSTRACT

The recent development of metropolitan cities, especially in Europe, requires an effective integrated management of city services, infrastructure, and communication networks at a metropolitan level. A preliminary step towards a proper organizational and management strategy of the metropolitan city is the analysis, benchmarking and optimization of the metropolitan areas through a set of indicators coherent with the overall sustainability objective of the metropolitan city. This paper proposes the use of the Analytic Hierarchy Process multi-criteria decision making technique for application in the smart metropolitan city context, with the aim of analysing the sustainable development of energy, water and environmental systems, through a set of objective performance indicators. Specifically, the 35 indicators defined for the Sustainable Development of Energy, Water and Environment Systems Index framework are used. The application of the approach to the real case study of four metropolitan areas (Bari, Bitonto, Mola, and Molfetta) in the city of Bari (Italy) shows its usefulness for the local government in benchmarking metropolitan areas and providing decision indications on how to formulate the sustainable development strategy of the metropolitan city. Based on the Analytic Hierarchy Process characteristics, the results highlight that although one specific area (Mola in the considered case) is globally ranked at the first place, it is only ranked first with respect to some dimensions. Such a result has strong implications for the metropolitan city's manager who has the possibility to identify and implement targeted actions, which may be designed ad hoc to improve specific dimensions based on the current state of the city, thus maximizing the efficiency and effectiveness of the actions undertaken for the sustainable development of energy, water and environmental systems of the whole metropolitan city.

1. Introduction

Modern cities are complex systems that accommodate massive number of citizens, businesses, different modes of transport, communication networks, services and utilities (Neirotti et al., 2014). Data about cities over the globe reveal that the world is experiencing an unprecedented level of urban population growth and urbanization (Dirks et al., 2009). Today, 55% of the world's population lives in urban areas, a proportion that is expected to increase to 68% by 2050. Projections show that urbanization, the gradual shift in residence of the human population from rural to urban areas, combined with the overall growth of the world's population could add another 2.5 billion people to urban areas by 2050, with close to 90% of this increase taking place in Asia and Africa (United Nations, 2018). This phenomenon raises a variety of technical, social, economic, and organizational problems that tend to jeopardize the economic and environmental sustainability of cities and make the sustainable development and better livability of cities imperative (Washburn et al., 2010). Among the challenges due to the expansion of cities, traffic congestion, air pollution, difficulty in waste management, and inadequate, deteriorating and aging infrastructures may be singled out (Toppeta, 2010). Another set of problems is social and organizational rather than technical, physical or material, and refers to the increasing social inequality and human health concerns (Kim and Han, 2012). Such phenomena impose governments to manage cities in an innovative way in order to avoid for urban population growth and urbanization to become critical issues (Carli et al., 2017). This has led to the current debate among governments and scientists on how new technology-based solutions and new approaches to urban planning and living can ensure the sustainable development and livability of cities (Dirks et al., 2009; Wang et al., 2017b). An emerging solution is the concept of smart cities, the new paradigm of intelligent urban development and sustainable socio-economic growth

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(Neirotti et al., 2014). To add to this complex environment, in the context of cities the recent developments in transport, communication, and information technology have increased material and information flows considerably, leading to a change from the traditional vision of city as distinct from its hinterland and from other cities to a new concept in which barriers between people living in and outside the city are disregarded, with regular commuters (e.g., students, workers, and people looking for healthcare or for cultural facilities). Economic activities, transport flows, and air pollution clearly cross the administrative boundaries of a city as well.

This evolution that is affecting modern cities, especially in Europe, has favoured the formation of metropolitan cities, which may be defined as the functional urban area that extends beyond the core city defined by administrative and/or political boundaries (Fujita et al., 2001). As a result, there is a general consensus on the need for a level of government that reflects the *de facto* city rather than the *de jure* city. Strategic planning as well as public policies on economic development, labor market, mobility, transport, housing, education, water, energy, waste, immigration, etc. cannot be addressed at a pure city level. Effective government and governance structures at a metropolitan level are indeed a key condition for the city competitiveness (Carli et al., 2014). The better a city is managed, the more competitive its position in the global metropolitan network. Hence, metropolitan cities are required to assume roles and responsibilities that embrace new tasks: the strategic development of the metropolitan areas (belonging to the metropolitan city) and the promotion and integrated management of services, infrastructure and communication networks at a metropolitan level.

The challenge is to make the metropolitan city closer to the needs of its users (inhabitants) in terms of better quality of services, reduction of the impact on the environment, containment of energy consumption, through the use of innovative technologies, namely, Information and Communication Technologies (ICTs). Governmental authorities are required to intervene in the coming years in order to make metropolitan cities “more accessible, functional and sustainable and, at the same time, more cohesive and inclusive” (Dipartimento per lo Sviluppo e la Coesione Economica, 2014). Such objective in the development of metropolitan cities may be reached by ensuring the diffusion and widespread use of ICT (i.e., improving the structural conditions in accessing Internet, making Internet available for families and individuals, also through an overall increase in digital skills widespread in the population) as well as by working through policies aimed at improving key aspects related to the energy, water and environment systems (Papa et al., 2016).

The sustainable development of energy, water and environment systems of metropolitan cities requires, as a first step, the analysis of the propensity and susceptibility of the individual metropolitan areas to adopt a sustainable development approach, measured through a set of indicators that are coherent with the objectives of the metropolitan city. In other words, to monitor the performance of a metropolitan city, its metropolitan areas (which are often represented by multiple towns of the metropolitan city) have to be analyzed and benchmarked across a common set of aspects that relate to sustainability. This requires an integrated approach to capture multiple aspects characterizing the concept of sustainable development of energy, water and environment systems, as proposed by (Kılkış, 2015) for cities, as well as the experience and preferences of the decision makers about the priority among these aspects (Boselli et al., 2015). While the literature provides several examples on benchmarking cities in only one aspect (Wang et al., 2017b), very few studies provide a composite cities' benchmarking indicator incorporating multiple aspects of sustainability as well as the preferences of the decision makers. To the best of author's knowledge, the few studies that pursue this objective (see (Kılkış, 2016) for a review) address the issue at country/city level, with no efforts at metropolitan city level. Although these few studies represent first attempts toward the direction of benchmarking cities in a holistic way, they do not provide operative indications about specific areas of intervention (e.g., sectors, neighborhoods) that need improvements in order to increase sustainability.

Hence, there is a clear need for decision making and performance analysis tools to measure the sustainable development of metropolitan cities. This paper advances the state of the art by providing an answer to such a need. It enhances the existing studies by developing a decision making and performance analysis tool to measure the sustainable development of metropolitan cities, which includes multiple aspects of sustainability as well as the preferences of the decision makers. This advancement is accomplished through the innovative application of the Analytic Hierarchy Process (AHP) multi-criteria decision making technique (Saaty, 2008) to the metropolitan city context, using a framework of indicators previously developed in the literature (Kılkış, 2015). Although AHP is a well-established technique for supporting local government decision makers, its application to the metropolitan city context, and particularly to the assessment of its sustainability based on multiple and contrasting dimensions, is new. Indeed, to the best of the authors’ knowledge, until now AHP has been used only for supporting local decision making initiatives related to urban environments, always with the aim of addressing specific issues encountered by local governments. For instance, it has been adopted for the sustainability assessment of local distributed energy systems (Väisänen et al., 2016), for the selection of optimal schemes for storage tanks under different rainfall scenarios (Wang et al., 2017c), and for the assessment of the capacity of agricultural landscapes to provide ecosystem services (ES) (Inkoom et al., 2018).

Through the application of the approach to the real case of the metropolitan city of Bari (Italy), it has been shown how the AHP-based approach may be used to support local government decision makers in benchmarking the metropolitan areas with respect to sustainable development and its multiple dimensions and, as a result, in providing decision indications on how to formulate the optimal strategy to promote the metropolitan city's process of innovation of its organizational and management structure.

The rest of the paper is organized as follows. Section 2 reviews the performance indicators that are currently used to assess the sustainable development of cities. Section 3 presents the formulation of the AHP model as a multi-criteria decision making tool for benchmarking metropolitan areas with respect to the sustainable development of energy, water and environment systems. Section 4 applies the proposed technique to the metropolitan city of Bari. Section 5 provides a summary of the paper with concluding remarks. A reference list closes the paper.

2. Literature review

The evolution of modern cities towards complex systems has spurred researchers to focus on the theme of sustainable development of cities, through a multi-disciplinary approach embracing discourses on science, technology and environmental policy related to the sustainability of humanity's activities (Urbaniec et al., 2016, 2017).

The analysis of the related literature reveals that most of the existing studies use quantitative and/or qualitative indicators to assess specific aspects of the sustainable development and benchmark cities on these aspects. For instance, recently some authors have focused on CO_2 emission factors and energy aspects. Yajie et al. (2014) present a model for measuring the carbon footprint of urban areas, that is a fundamental quantization parameter of carbon emissions measurement, thus contributing to providing benchmarks and expanding the understanding of carbon emissions. Tan et al. (2017) establish an indicator framework for the evaluation of low-carbon city from the perspectives of economic, energy pattern, social and living, carbon and environment, urban mobility, solid waste, and water. The framework is then applied to ten cities to rank their low-carbon levels. Wang et al. (2017b) develop an urban energy performance evaluation system, for determining the energy performance level based on input-output analysis as well as