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Evaluating the performance of sustainable development in urban neighborhoods based on the feedback of multiple stakeholders

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ABSTRACT

Sustainable development (SD) has increasingly become a major priority in urban neighborhoods to maintain social quality of life and support their economic development while preserving the environment. To expand the use of SD in urban neighborhoods, local governments often adopt various strategies such as land use planning. The priorities and effectiveness of these strategies vary significantly for different stakeholders such as neighborhood communities and local governments because of their different and often conflicting interests. Accordingly, there is a pressing need to integrate the performance evaluation of SD strategies from all urban planning stakeholders to ensure that the conducted evaluation is comprehensive and representative of all the affected stakeholders. Although there are several studies that focused on evaluating SD in urban areas, there is still a need for a comprehensive model that is capable of integrating the varying evaluations of different SD stakeholders. Accordingly, this paper presents the development of a comprehensive and an effective model for evaluating the performance of SD that is capable of integrating the varying and often conflicting evaluations of various stakeholders. The model is developed in four main stages: (1) formulation stage that created a comprehensive set of sustainable development (SD) criteria for urban neighborhoods; (2) group decision making stage that integrates the evaluations and judgments of multiple stakeholders; (3) implementation stage that automated the model computations; and (4) performance evaluation stage that analyzed the performance of the developed model using an application example.

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1. Introduction

Sustainable development has increasingly become a major priority in recent years in urban planning. Sustainable development in urban neighborhoods focuses on three main objectives: (1) improving social quality-of-life for urban neighborhood residents, (2) expanding economic development and promoting economic growth in urban areas, and (3) increasing environmental protection practices in the developed areas (WCED, 1987). These three objectives have different priorities for various stakeholders in urban planning such as local authorities, households, prospective investors, NGOs because of their different and often conflicting interests (Galster, 2001; McKnight, Kretzmann, Northwestern University. Center for Urban, Policy, & Neighborhood Innovations, 1990). Therefore, there is a pressing need for a model that is capable of integrating these varying priorities and supporting a group of urban planning decision-makers in their critical and challenging task to evaluate the performance of various SD strategies in order to create a common desirable SD for all affected stakeholders.

Several studies were conducted to evaluate existing SD conditions in urban areas and potential SD strategies that can be implemented to promote the sustainability of urban neighborhoods (Applied Population Laboratory, University of Wisconsin, & the City of Madison, 2012; Boston Foundation, City of Boston, & The Metropolitan Area Planning Council, 2009; Central Texas, 2009; City of Santa Monica, Dept. of Community and Cultural Services, & Human Services Division, 2003; Meter & Crossroads Resource Center, 1999; Sustainable San Mateo County, 2012). Other research studies focused on analyzing (a) the sustainability of construction projects (Reyes, San-José, Cuadrado, & Sancibrian, 2014), (b) the level of service and quality of neighborhood infrastructure systems

Abbreviations: SD, sustainable development; SQOL, social-quality of life; ECON, economic development; ENV, environmental protection; SDI, sustainable development index; DM1, a member from local authorities; DM2, a member from neighborhood community; DM3, a member from NGOs.

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Nomenclature

Notations

m_x	metric value of the continuous metric
m_x^-	worst level of performance for m_x
m_x^+	best level of performance for m_x
$U_x(m_x)$	utility function for 'x' different metrics from m_1 to m_x
α	adjustment factor ensuring that $0 \le U_x(m_x) \le 1$
γ	parameter for defining the shape of the curve where $\gamma > 1$ makes the curve convex or S-shaped, $\gamma = 1$ makes the curve linear with a constant slope, and $\gamma < 1$ makes the curve concave; m_λ is the metric for defining the inflection point on the x-axis if $\gamma > 1$
m_λ	metric value for defining the inflection point on x-axis of Fig. 1B if $\gamma > 1$
$U(m_\lambda)$	utility value for defining the inflection point on y-axis at the point of m_λ
W_i	collective group weight for the ith metric, criterion, or objective
K	total number of decision-makers in the group
I	total number of elements in the metrics, criteria, and objectives set
w_i^k	kth group member's weight for the ith metric, criterion or objective in the set
α_k	influence of kth decision-maker on decision-making process
Z	total number of sustainable development objectives
W_z	weight for the zth objective
Y	total number of criteria such as public safety and education
W_{yz}	weight of a group of decision-makers for the yth criterion in the zth objective
X	total number of metrics for quantifying the performance of the yth criterion
W_{xyz}	weight of a group decision-makers for the xth metric of the yth criterion in the zth objective
U_{xyz}	utility value of the xth metric of the yth criterion in the zth objective

such as urban roads (Sayyadi & Awasthi, 2012; Sharma, Al-Hussein, Safouhi, & Bouferguène, 2008), and (c) regional sustainable developments (Chatzimouratidis & Pilavachi, 2009; Kurka, 2013). The US Green Building Council (USGBC) also developed a neighborhood development rating system called Leadership in Energy and Environmental Design for Neighborhood Development (LEED-ND) in 2009. LEED-ND is a rating system including credits to evaluate the performance of SD in neighborhoods. LEED-ND credits address the importance of local conditions in determining best environmental design and construction practices as well as social and health practices (USGBC, 2009). Despite the significant contributions of the aforementioned studies and existing standards, there is little or no reported research that focused on evaluating and quantifying SD performance in urban neighborhoods that is capable of integrating varying evluations from multiple stakeholders.

2. Objective

To address the aforementioned research gaps, this paper presents the development of a comprehensive and an effective model for evaluating the performance of sustainable development in urban neighborhoods that is capable of integrating the varying and often conflicting evaluations of various stakeholders. The model is developed in four main stages: (1) SD criteria stage that identifies a comprehensive set of sustainable development (SD) criteria for urban neighborhoods; (2) group decision making stage that integrates the evaluations and judgments of multiple stakeholders; (3) implementation stage that automates the model computations; and (4) performance evaluation stage that analyzes the performance of the developed model using an application example. The following sections of the paper provide a concise description of these four development stages of the model.

3. Sustainable development criteria

This stage of model development focuses on creating a comprehensive set of criteria for assessing sustainable development in urban neighborhoods. This comprehensive set of criteria was developed in the following three main steps. First, a detailed list of criteria for assessing SD in urban neighborhoods were gathered from previous research and reported criteria that were used in sustainable development projects in five different states (Applied Population Laboratory et al., 2012; Central Texas, 2009; City of Santa Monica et al., 2003; Meter & Crossroads Resource Center, 1999; Sustainable San Mateo County, 2012). Second, the gathered list of criteria was analyzed to develop a comprehensive, practical, reliable and effective set of criteria that will be integrated in the developed model. This developed criteria list was identified to ensure that each selected criterion is: (a) simple, (b) measurable using quantitative values or qualitative expressions, (c) independent of other criteria, and (d) can be easily understood and evaluated by decision-makers (Barrera-Roldán & Saldı′var-Valdés, 2002; Keeney, Meyer, & Raiffa, 2003; Sun, Ni, & Borthwick, 2010; Wang, Jing, Zhang, & Zhao, 2009). Third, the developed set of SD criteria was organized in a hierarchy that represents: (1) the three main objectives of SD of social quality-of-life (SQOL), economic development (ECON), and environmental protection (ENV); (2) the identified set of SD criteria for each of the three SD objectives; and (3) the metrics that can be used to evaluate the performance of each SD criterion, as shown in Table 1.

4. Group decision-making

This stage of the model focuses on developing a model that is capable of integrating the evaluations of SD performances from multiple stakeholders. Accordingly, the model is designed to: (a) consider and aggregate the performance in various metrics with different measurement units (e.g., minutes, crime frequency); (b) enable the integration of feedback from multiple stakeholders; and (c) compute an index which allows multiple decision-makers to quantify the performance of SD in urban neighborhoods. To accomplish this, the present model utilizes multi-attribute utility theory (MAUT) and analytic hierarchy process (AHP). MAUT was used in the present model due to its simplicity, ability to consider multiple objectives, and providing easy to understand output information, and relevance to real world problems (Clemen & Reilly, 2001; Keeney & Raiffa, 1976; Prato, 2000; Tsoutsos, Drandaki, Frantzeskaki, Iosifidis, & Kiosses, 2009). The AHP was used in the model to enable reliable integration of varying priorities from multiple stakeholders (Dyer & Forman, 1992; Forman & Peniwati, 1998; Saaty, 1980). The computations in the model are performed using the following three steps: (1) quantifying performance in SD metrics; (2) identifying weights of SD metrics, criteria and objectives; (3) computing overall SD index.

4.1. Quantifying SD metrics

In order to quantify the performance in all the identified SD metrics, a set of utility functions were developed $U_1(m_1)$, $U_2(m_2)$, ...,

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