Ecological Indicators 34 (2013) 361–371

Contents lists available at SciVerse ScienceDirect

Ecological Indicators

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

Developing an indicator system for local governments to evaluate transport sustainability strategies

Tzay-An Shiau[a,*], Jung-Shan Liu[b]

[a] Department of Harbor and River Engineering, National Taiwan Ocean University, 2, Pei-Nein Road, Keelung 20224, Taiwan
[b] Department of Harbor and River Engineering, National Taiwan Ocean University, Taiwan

ARTICLE INFO

Article history:
Received 6 December 2012
Received in revised form 29 May 2013
Accepted 2 June 2013

Keywords:
Transport sustainability
Indicator system
Fuzzy Cognitive Maps (FCMs)
Cause–effect relationship
Analytic Hierarchy Process (AHP)

ABSTRACT

This study proposed an indicator system for measuring and monitoring transport sustainability at the county (or city) level. Twenty-one indicators were grouped into economy, environment, society, and energy aspects. A committee comprised of government officials from Taipei City and New Taipei City proposed transport solutions to improve the transport sustainability of the Taipei metropolitan area. Ten key indicators were selected to measure the sustainable transport strategies. This study applied Fuzzy Cognitive Maps (FCMs) and the Analytic Hierarchy Process (AHP) to construct the cause–effect relationships between these key indicators and to evaluate sustainable transport strategies. The evaluation results showed that the strategy of expanding mass rapid transit (MRT) lines was predicted to produce the most significant improvements; the strategy of integrating bus exclusive lanes would provide the least improvement; and the strategies of promoting cleaner vehicles and integrating Fu-Kang bus resources would perform similarly to each other in improving transport sustainability.

1. Introduction

Improving transport sustainability has been a focus in response to global climate change around the world. Indicator systems for measuring transport sustainability have been broadly explored. For example, the European Environment Agency (EEA) has reported annually on a series of transport sustainability measurements in its "Transport and Environment Reporting Mechanism" (TERM) publication since 2000, subject to data availability (EEA, 2011). Most of the literature has been concerned with transport sustainability at the national level, and there is a lack of indicators for monitoring local development of transport sustainability at the local level.

Taiwan is a member of the global village and shares the responsibility of sustainable development. The Council for Economic Planning and Development (CEPD) of the Government of Taiwan prepared "Taiwan Agenda 21: Vision and strategic guidelines for national sustainable development," which outlines Taiwan's implementation of Agenda 21, and submitted the document to the United Nations Council on Sustainable Development (UNCSD). The definition of transport sustainability has a broad scope and involves specific transportation issues. As defined by the European Council of Ministers of Transport (ECMT, 2004), transport sustainability has the following characteristics:

- "It allows the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations.
- It is affordable, operates fairly and efficiently, offers a choice of transport mode and supports a competitive economy, as well as balanced regional development.
- It limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise."

Transport sustainability is becoming a common vision for Taiwan's central and local governments. Shiau and Jhang (2010) proposed a generalized efficiency indicator system to evaluate the transport sustainability of Taiwan. The evaluation system was a "tailor-made" framework for decision makers, and created only five generalized efficiency indicators, termed cost efficiency, cost effectiveness, service effectiveness, service reduction, and service impact indicators. This study applied Data Envelopment Analysis (DEA) and Rough Sets Theory (RST) to obtain the rank of transport sustainability and useful decision rules for initiating improvement strategies. For broad application, Shiau et al. (2013) proposed a

* Corresponding author. Tel.: +886 2 24622192x6141; fax: +886 2 28051647.
E-mail addresses: sta@mail.ntou.edu.tw, snowfrank66@yahoo.com.tw (T.-A. Shiau).

1470-160X/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ecolind.2013.06.001

Fig. 1. Taipei metropolitan area.

framework to generate and select transport sustainability indicators for both decision makers and planners. Additionally, two-stage Principal Component Analysis (PCA) was applied to measure the transport sustainability in Taiwan. These studies measured the transport sustainability at the country level. The present study proposes an indicator system for measuring transport sustainability at the county (or city) level, and provides local governments with a basis for evaluating transport sustainability strategies.

Gudmundsson and Sørensen (2012) investigated that the "use" of transport sustainability indicators does not automatically mean "influence" on policies. This point of view magnifies the importance of policy implementation. In response to global climate change, local governments have paid increasing attention to measures that improve sustainable development of transportation. Kepaptsoglou et al. (2012) proposed a quality management scheme in mobility management to support cities' transport sustainability. Haghshenas and Vazari (2012) compared various world cities using sustainable transport indicators. Marsden and Rye (2010) used a multi-level governance framework to understand the policy environment in England and Scotland, capturing both the range of spatial actors and the influence of sectoral actors in what is a complex polity. Banister (2011) concluded that there are opportunities for cities to switch to low carbon transport futures. Reddy and Balachandra (2012) suggested policies to reduce energy consumption and emissions for improving transport sustainability of metropolitan areas in India. Drumheller et al. (2001) summarized 52 different transportation-related actions for local governments. One weakness in these reports are the lack of a comprehensive evaluation of various transport options. Awasthi and Chauhan (2011) proposed a Transport Sustainability Index (TSI) for measuring the impact of a carsharing strategy on city sustainability. Their results showed that a carsharing strategy can improve the transport sustainability of a city. Nine criteria regarding sustainability were initiated. Some of the criteria were correlated (e.g., fuel consumption and air quality) but their effects were not taken into account. Browne et al. (2008) compared the ecological footprint of travel-commuting patterns for the residents of an Irish city-region, but did not include comprehensive sustainability considerations. Their results showed that reduced transport demand and technological improvements in fuel economy are the optimal policy mix, and that no one policy strategy is a panacea for sustainable transport. Yedla and Shrestha (2003) evaluated the priority of three alternative transport options applied in Delhi, including 4-stroke 2 wheelers, Compressed Natural Gas (CNG) cars, and CNG buses. Energy saving potential and emission reduction potential were correlated, but their effects were not taken into consideration. Shiau (2012) evaluated fifteen strategies for improving the transport sustainability of Taipei, the criteria covering the aspect of society, environment, economy, energy, and finance were considered in evaluation process, their inter-related effects were also ignored. Fitzgerald et al. (2012) evaluated various policies to enhance urban sustainability using quantitative method. The policy impacts on transport, environment, socio-economics and quality of life aspects were independently considered. Jones et al. (2013) defined a scoring system, in terms of Localized Sustainability Score (LSS) to rank urban transport projects to reflect local circumstances. Their research focus was to evaluate transport projects of different scales.

Dependency between various indicators is a common problem in measuring transport sustainability; this problem can be easily solved by using Principal Component Analysis (PCA). Shiau et al. (2013) proposed a two-stage PCA to measure the transport sustainability of Taiwan; the interrelated indicators were transformed into independent principal components. However, PCA is a data-driven approach; this approach is applicable in analyzing historical data and is unsuitable for predicting the possible outcomes caused by introducing transport strategies. Fuzzy Cognitive Maps (FCMs) are useful in relationship management. For example, Kang et al. (2004) applied FCMs to manage the relationships among organizational members in airline service. Khan and Quaddus (2004) proposed a group decision support framework for causal reasoning using FCMs. The present study applies FCMs to construct the cause–effect relationship between various transport sustainability indicators, and then the FCMs are used to evaluate the strategies for improving transport sustainability in the Taipei metropolitan area. An intercity communication platform was established by creating a committee comprised of officials from the governments of Taipei City and New Taipei City. The Analytical Hierarchy Process (AHP) was used to elicit the preferences of the committee members.