Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 145 (2016) 34 – 41

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Sustainable Design, Engineering and Construction

A Simulation Framework for Sustainability Assessment in Evolving Socio-Technical Infrastructure Systems

Mostafa Batouli[a,*], Ali Mostafavi[b]

[a]*PHD Candidate, Department of Civil and Environmental Engineering, Florida International University*
[b]*Assistant Professor, OHL School of Construction, Florida International University*

Abstract

Sustainability of infrastructure systems involves multiple interrelated objectives which are dependent on the dynamic behaviors of stakeholders, interdependencies between infrastructure assets, and evolving conditions in the social and environmental systems. This research contributes to the body of knowledge by creating a framework that integrates: (1) different dimensions of sustainability in infrastructure networks, and (2) dynamic changes in the behaviors of stakeholders, asset performance conditions, and the social and environmental conditions. The proposed framework includes an agent based simulation model to capture the dynamic behaviors of decision makers and the evolving performance of infrastructure assets under different socio-environmental conditions. The outcomes of the simulation model include the short- and long-term costs and environmental impacts of infrastructure networks under different scenarios related to the changes in the socio-environmental conditions. The application of the framework is shown in a numerical case study of a road network. The results include: (i) identification of infrastructure management strategies (e.g., maintenance planning and funding allocation) that optimize the tradeoff between annual cost and environmental impacts of the network; and (ii) discovering robust management strategies that lead to highly-likely desired sustainability outcomes across different uncertain scenarios related to the future socio-environmental conditions. The results show the capability of the proposed framework for sustainability assessment of infrastructure systems based on integrated analysis of the dynamic behaviors of decision-makers, infrastructure characteristics, and evolving socio-environmental conditions. Hence, it provides a predictive quantitative tool to inform decision-making and policy formulation toward improving the sustainability of infrastructure networks.

Peer-review under responsibility of the organizing committee of ICSDEC 2016

Keywords: Sustainability assessment, Infrastructure Systems, Agent based Simulation

* Corresponding author. Tel.: (305) 348-3172; fax: (305) 348 6255.
E-mail address: sbatouli@fiu.edu

Peer-review under responsibility of the organizing committee of ICSDEC 2016
doi:10.1016/j.proeng.2016.04.006

1. Introduction

American Society of Civil Engineers has listed sustainable development of infrastructure systems as one of the three strategic priorities of the nation [1]. Over the past few decades, life cycle assessment (LCA) and life cycle cost analyses (LCCA) have become predominant approaches to evaluate the environmental and economic sustainability of infrastructure. However, LCA and LCCA have major limitations for assessing sustainability of infrastructure systems at network level:

(i) Both LCA and LCCA focus on single entities (i.e. assets). However, infrastructure systems are networks in which budgetary and functional interdependencies between individual assets play an important role in the overall functioning and performance of the system [2]. The existing LCA and LCCA methods do not consider these interdependencies in sustainability assessment of infrastructure networks.

(ii) The sustainability performance of infrastructure networks is contingent upon the adaptive behaviors of various individuals and institutions involved in management and operation of technical systems. In this paper, these individuals and institutions are referred to as "administrative agency" or "agency". The existing LCA and LCCA do not consider the dynamic decision making of the administrative agency in terms of preservation prioritization and budget allocation and therefore are unable to study the evolutionary sustainability performance of infrastructure systems [3].

(iii) Each sustainability assessment method offers indicators related to one dimension of sustainability. For example, LCA considers indicators of environmental sustainability and LCCA offers an economic indicator for sustainability assessment. Assessing different dimensions of sustainability using independent indicators leads to loss of important information about the correlation between different sustainability objectives [4]. Addressing this limitation requires development of methodologies that integrate assessment of various sustainability objectives to attain better understanding about the correlations and trade-offs between different sustainability indicators [5].

The objective of this study is to create a methodology for assessing the evolutionary sustainability performance of infrastructure systems as a result of dynamic interactions between the physical networks and the administrative agency.

2. Framework for assessing evolutionary sustainability in infrastructure systems

In order to capture the evolutionary sustainability performance of infrastructure systems, a framework consisting of three major components is proposed (Fig. 1). As shown in Fig. 1, socio-environmental conditions such as changes in service demand and the level of funding availability for network preservation may lead to adaptive behaviors in the agency's decision making processes, which ultimately affect the condition of the physical network. On the other hand, the condition of the physical network influences the decision-making behaviors of the agency in terms of prioritization of renewal projects. The interactions between physical network and agency lead to a stable performance state for the network. A stable performance state is associated with certain level of performance as well as cost and environmental impacts. This stable state is referred to as the performance regime of the network. One important objective of this research is to study the correlation/tradeoff between different sustainability objectives in the performance regime of infrastructure systems.

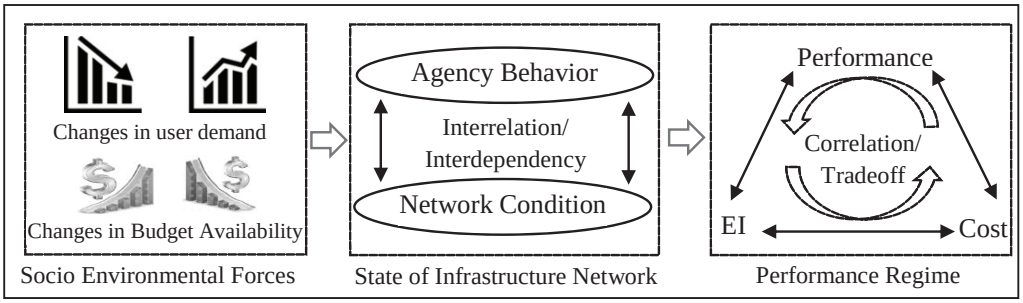

Fig. 1. Framework for Assessing Evolutionary Sustainability Performance in Infrastructure Systems