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ScienceDirect

Procedia Computer Science 28 (2014) 81 – 86

Procedia Computer Science

Conference on Systems Engineering Research (CSER 2014)

Eds.: Azad M. Madni, University of Southern California; Barry Boehm, University of Southern California; Michael Sievers, Jet Propulsion Laboratory; Marilee Wheaton, The Aerospace Corporation
Redondo Beach, CA, March 21-22, 2014

Conceptual Modeling of the Impact of Smart Cities on Household Energy Consumption

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Abstract

Smart cities provide citizens with information on various urban services and allow them to track the impact of their resource consumption on the overall sustainability of their city. The premise of smart cities is that with improved access to information on resource consumption, residents make better use of those resources, resulting in increased sustainability of the city.

This paper explores the influence of the smart city technologies on individuals' resource consumption behavior, in particular on energy consumption, aiming at achieving environmentally sustainable development. This approach combines systems thinking with existing social science theories, such as cognitive and learning theories, to explore the impact of smart city information on individual decision-making and behavioral change. Using a CLIOS (complex, large-scale, interconnected, open, and sociotechnical) model, a conceptual soft systems model, the paper explores the impact of smart city technologies on behavioral change of households with regards to energy consumption.

Keywords: Smart city; Information and Communication Technology; Energy Behavior; Behavior Change; Conceptual Systems Model; CLIOS Model.

doi:10.1016/j.procs.2014.03.011

1. Introduction

The world population is expected to reach to nine billion in 2050. The population growth rate is more significant in developing countries. Accordingly, providing the basic needs of human beings such as space and basic materials to live implies a further increase in environmental impacts[1]. However, Natural resources are limited. On the other hand, energy demands and costs are increased over time[2]. Increasing usage of energy-intensive products and services directly affect greenhouse gas emissions and climate change[3]. Since the beginning of 20th century, the global mean of surface temperature has increased by 0.6°C. The northern hemisphere surface temperature has increased more in the 20th century than the previous 1,000 years. The warmest decade of the millennium was the 1990s and the warmest year was 1998[4]. The National Academy of Sciences (NAS) predicts a global mean surface air temperature increase of 2.5 to 10.4°F between 1990 and 2100 due to increasing greenhouse gases[5]. Therefore, there is urgent need to a move towards urban sustainability and in particular reducing energy consumption. Recent studies show that information and Communication Technologies (ICTs) play an active role in reaching the goals of urban sustainability. Benefiting from ICTs, we can reduce energy costs, increase energy efficiencies, and improve the quality of life in cities[6]. The utilization of ICTs by citizens, service providers and city government has formed the general concept of a smart city.

In smart cities, governments and businesses invest in ICTs to improve sustainable development and quality of life, by providing smart urban infrastructures that will inform residents about the desired environmental agenda[7]. In fact, a smart city provides the required infrastructure for citizens and officials to make more intelligent decisions. In doing so, it plays an essential role in dealing with challenges relating to ecological, social, cultural, and economic sustainability[8].

Smart cities provide citizens with information on various urban services and allow them to track the impact of their resource consumption on the overall sustainability of their city. The premise of smart cities is that with improved access to information on resource consumptions, residents make better use of those resources, resulting in increased sustainability of the city. This paper explores the influence of the smart city technologies on individuals' resource consumption behavior, in particular on energy consumption, aiming at achieving environmentally sustainable development. This approach combines systems thinking with existing social science theories, such as cognitive and learning theories, to explore the impact of smart city information on individual decision-making and behavioral change. Using a CLIOS model, the paper explores the impact of smart city technologies on behavioral change of households with regards to energy consumption. CLIOS process as an organizing mechanism helps to understand the structure and behavior of system and identify strategic options for improving, developing, and monitoring system's performance and strategic alternatives[9].

The paper maps the impact of information technologies on the individual's energy-related decision-making process. The paper further discusses the role of information technologies as a way for residents to change energy behaviors and explores the mechanisms by which information sharing enables overcoming resistance against change. The model shows how communication and collaboration within an urban system can result in more effective energy structures and practices.

The paper is organized as follows. First, section II represents social science theories, such as cognitive and learning theories, that can be utilized to explore the impact of smart city information on individual's decision-making and behavioral change. Then, in Section III, the authors explore strategies to influence behavioral change. Section IV presents a conceptual CLIOS model to investigate effects of information feedback and socioeconomic structure in managing energy consumption behavior. Finally, conclusions are drawn in Section V.

2. Theoretical Background

According to social learning theory, the result of interactions between personal and environmental variables identify behavior. Although environment plays a key role in shaping behavior though learning, environment, itself, is shaped by individuals. Individuals' behavior is the result of direct experience, observational, or vicarious learning[10]. Social learning theories express that most behaviors lead to consequences that in turn feedback to behavior, either maintaining or changing behavior in the future[11]. Social cognitive theory explores that neither environment nor inner forces control individuals. Social cognitive theory addresses "an agentic conceptual framework to analyze the