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Energy Consumption and Quality of Life: Energy Efficiency Index

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Abstract

This paper shows a micro-economic based quantitative analysis scheme to evaluate the energy efficiency of cities based on quality of life and energy consumption. By representing the quality of life by utility, this study developed a CES-based model to estimate the individual demand of non-mobility goods, car trips, and public transport trips at the maximum utility level. Energy consumption is estimated by the demand of goods. An energy efficiency index is developed to show the relative energy consumption on the certain quality of life. We applied this model to Nagasaki region. Higher energy efficiency zones were found in city center and along the mass transit lines. Such findings suggest that a compact urban structure and higher public transport accessibility could increase energy efficiency.

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Keywords: Energy consumption; Quality of life; Consumption behavior; Energy efficiency

1. Introduction

Sustainable urban development has being a crucial element affecting the long-term outlook of humanity [1][2]. Growing concerns about urging oil prices and greenhouse gases produced by burning fossil fuels require the urban development to minimize the use of resources, spatial displacement of environment and improve energy efficiency [3][4][5]. Energy consumption by urban activities has often

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become a major concern. The intensity of activities, such as traffic and industry, are seen as major factors influencing energy consumption. Energy consumption is strongly related to actual land use and transportation as well as population density. Urban activities like production and consumption have been supported by consumption behaviors and transportation service which distribute goods [6].

Various kinds of consumption behavior also affect the achievement of quality level of life. More consumption of goods is believed closely related to the quality of life. It would influence the quality of life of individuals if we aim to reduce energy consumption through consumption behaviors. It is usually believed that reduced energy consumption means decreasing the quality level of life. Few studies focus on the goal of energy consumption reduction meanwhile considers the quality of life. It is important to consider the quality of life when we make policy aiming for reducing energy consumption [7].

This paper aims to introduce energy efficiency as a new index to evaluate the relative achievement of energy reduction. This index considers both energy consumption and quality of life. A model is built to estimate the energy consumption based on consumption of goods for present quality of life. We also apply the model into Nagasaki region to explore the energy efficiency of zones.

2. Method

2.1. Subsidy, cost, and revenue

All consumption behaviors of residents are classified as consumption behaviors for non-mobility goods and mobility goods. Mobility goods include car trips and public transport trips. Non-mobility goods are defined as all other goods except mobility goods. Specially, non-mobility goods include goods in the Residential and Commercial sectors, such as heating, cooling, food and recreation. Following assumptions are essential parts for the approach to estimate demand of goods: a) A resident is assumed to consume two types of goods: non-mobility goods and mobility goods. b) The demand of mobility goods is a function of car trips and public transport trips. c) Individuals are supposed to achieve maximum utility and maximum mobility at same time. d) All income is spent on consuming without saving. e) Present level of quality of life is expressed by the maximum utility.

2.2. Quality of life and utility

Quality of life is the general well-being of individuals and societies. There are many indexes to quantify it. Utility is one of them from microeconomic viewpoint. People are supposed to achieve the well-being by consumption of goods. In microeconomics, utility represents satisfaction experienced by the consumer of a good [4]. People are assumed to make decisions based on their preferences over different goods, the cost of goods, and the budget constraints (income) to maximize the utility[8].

A two order Constant Elasticity of Substitution (CES) function are applied to express the relationship between utility, mobility, and demand of goods (Eq. (1) and Eq. (2)).

$$u_i(x_{1i}, x_{2i}) = \left\{\alpha_1 x_{1i}^{(\sigma_1-1)/\sigma_1} + \alpha_2 x_{2i}^{(\sigma_1-1)/\sigma_1}\right\}^{\sigma_1/(\sigma-1_1)} \quad (1)$$

$$x_{2i}(x_{2Ci}, x_{2Mi}) = \left\{\alpha_{2C} x_{2Ci}^{(\sigma_2-1)/\sigma_2} + \alpha_{2M} x_{2Mi}^{(\sigma_2-1)/\sigma_2}\right\}^{\sigma_2/(\sigma_2-1)} \quad (2)$$

where u_i indicates utility level. x_{1i}, x_{2i} are demand of non-mobility goods and mobility goods, respectively. x_{2Ci}, x_{2Mi} are demand of car trips and public transport trips, respectively; σ_1 represents substitution elasticity between non-mobility goods and mobility goods; σ_2 is substitution elasticity between car trips and public transport trips; α_1, α_2 are expenditure share of non-mobility goods and