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Development of an Appropriate Model for Forecasting Municipal Solid Waste Generation in Bangkok

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Abstract

Municipal solid waste (MSW) is a result of human activities. Accurate forecasting of MSW generation is crucial for sustainable management systems and planning. MSW is considered as an important resource for renewable energy development plans of cities. Due to the uncertainties and unavailability of sufficient MSW generation information in developing countries, including the difference of local conditions, various modeling methods were developed to predict MSW generation. The objectives of this paper are to identify influential variables that affect the amount of MSW generation and to predict the future MSW in Bangkok by employing linear and nonlinear models. The major factors of MSW in these two models are accounted by number of residents, people aged 15-59 years, number of households, income per household, and number of tourists. In the linear model, principal component analysis is capable to reduce multi-collinearity factors. This leads to the improvement of the performance of regression by a stepwise algorithm with R^2=0.86. In the nonlinear model, artificial neural network (ANN) is conducted by designing an appropriate network architecture in the Matlab tool. This approach with one neuron demand in hidden layer exhibits the fitting value of R^2=0.96, which is better than linear regression model. In these regards, the designed network in ANN is possibly stored for further analysis under the same conditions for high percentage of accuracy. All the results in this research can be utilized as part of solid plans for renewable energy development and eco-environmental recycle industry which require MSW as raw material.

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Keywords: Municipal solid waste, MSW quantities prediction, Regression analysis, Artificial neural network, Bangkok;

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1. Introduction

Solid waste produced by human activities, is a serious problem, particularly in many developing countries due to changes in consumption patterns and uncontrolled urbanization [1]. The way these wastes are handled, stored, and collected may cause risks to the environment and public health, as well as increase the expenditures on management systems. Municipal solid waste (MSW) management is a concern of megacity authorities in the world. MSW comes from community activities, such as household, commercial, institutional, fresh market, and construction and demolition (C&D) wastes, excluding hazardous and infectious wastes [2]. MSW composition is composed of organic, paper, plastic, glass, metals, and other waste [3]. Knowing the nature of solid waste generation, such as its amount and characteristics/composition, including calorific value, is a fundamental management activity. This leads to get the planning, operation and optimization of waste management systems. To get this information, a number of researchers collected the previous-year related data and predicted MSW amount. Since prediction of MSW amount cannot be done directly and depends on many factors, so appropriate modelling methods are required [1].

According to the review of waste prediction models, many different variables were focused on, such as number of residents, income, household size, residency type, age groups, employment, electricity consumption, tipping fees, consumer price index (CPI), gross domestic product (GDP), level of education, culture, geography, and climate [4].

To develop relationships between variables and waste generation, many researchers used regression analysis and time-series models [4]. Ghinea, et al. [5] used regression analysis and time series to forecast municipal solid waste generation and composition in Iasi, Romania. The data, such as the number of inhabitants, population aged 15 to 59 years, urban life expectancy, and amounts of municipal solid waste generated were used as input variables. The results revealed that population aged 15 to 59 years and total MSW were significant factors for the analysis and strongly influenced the waste fraction generation. For time series analysis, S-Curve trend model was the most suitable for MSW prediction both total waste and waste fraction. Daskalopoulos, et al. [6] predicted MSW generation rate and composition in the European Union countries and the United States of America by using polynomial equation to fit the model. The input variables were gross domestic product (GDP) and population. The results revealed that linear equation could indicate the general trend for most of the fractions but not give their real measured values, while third degree of polynomial equation provided the best fit curves for majority of the waste fractions.

Beside regression analysis and time series, artificial neural network (ANN) is also a popular and useful tool for predicting solid waste in developing countries where MSW generation data are missing or incomplete[1]. Noori, et al. [7] applied ANN and multivariate linear regression (MRL), which based on principal component analysis (PCA), to predict the solid waste generation in Tehran for short-term prediction. Weekly time series model of WG with 12 lag time (equal a season) and the number of trucks which carried waste in week were the input data. The results showed that ANN which is nonlinear and dynamic modelling technique had better results in comparison with PCA-MLR model. ANN was also successfully used by Antanasijević, et al. [8] to model and forecast MSW generation in Bulgaria and Serbia. The result demonstrated that ANN could be applied on national scale with the broad scope for possible application of the model.

Bangkok is an example of municipal in developing countries facing an increasing trend of waste throughout the decades, and it is chosen as case study in this paper.

2. MSW situation and management in Bangkok, Thailand

Bangkok is the capital city of Thailand, and it is divided into 50 districts and 154 sub-districts. The total area of Bangkok is 1,568,737 sq. km with a registered population of 5.7 million. However, taking into account of non-registered population which was about 2.6 million people, it made Bangkok become one of the world largest populated urban cities. On top of that, there were 38 million visitors from around the world visit Bangkok in 2010[9]. This lead the huge amounts of MSW to be generated daily in the city. Bangkok MSW generation increased from 8,291 tonnes/day to 11500 tonnes/day or 1.22 kg/capita/day to 1.33 kg/capita/day within 10 years (2005 to 2015) [10]. Waste generation rate increases as changing of population and lifestyle, so reducing activities (3Rs) may not enough to prevent the problems. Sustainable solutions and central MSW treatment/disposal with suitable technology are nessessary to reduce MSW disposal cost and produce energy as by-product. Therefore, MSW