IMPROVEMENT OF AN SUITABLE MODEL FOR PREDICTING MUNICIPAL SOLID WASTE PRODUCTION

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ABSTRACT

The 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 R2=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 R2=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.

KEYWORDS: Predictive Analysis, Urban Planning, Innovation Adoption

1.0 INTRODUCTION

Predictive Solid waste produced by human activities, is a serious problem, particularly in many developing countries due to changes in consumption patterns and uncontrolled urbanization [1-5]. 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 [6-10]. MSW composition is composed of organic, paper, plastic, glass, metals, and other waste [11-15]. 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 [16-20]. 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 [20-25]. To develop relationships between variables and waste generation, many researchers used regression analysis and time-series models 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. [26-30] 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. Many 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 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 [30-39].

2.0 CASE STUDY

The 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. 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 necessary to reduce MSW disposal cost and produce energy as by-product. Therefore, MSW generation forecasting should be conducted in order to know the amount of MSW which will be generated in the future. The objectives of this paper are to identify influential variables affect the amount of MSW generation and to develop an appropriate model to forecast amount of municipal solid waste in Bangkok, Thailand.

3.0 METHODOLOGY

Possible indicators are collected, such as waste-related indicator (Total municipal solid waste), population indicators (Total number of residents, Native residents, Total native people aged 15-59 years and Total people aged 15-59 years), dwelling indicator (Number of households), economic indicator (Income per household), and external indicator (Number of tourists), from 2005 to 2015. Missing data is deal by imputation, which missing values are substituted by others [1-10]. We use interpolation technique and average value substitution with total number of residents. At the same time, income per household is substituted by the average value because the survey of income per household in Bangkok is biennial made. Pearson Correlation is used to search for multi-collinearity between variables as shown in Table 2. Pearson Correlation table shows that waste generation is positively correlated with total number of residents, total people aged 15-59 years, number of households, income per household, and number of tourists, but negatively correlated with native residents and native people aged 15-59 years. Simultaneously, some variables also have strongly correlation with each other. So instead of use these variables directly, we change them into principal components [11-17]. Principal Component Analysis, one of the multivariate statistical method, is used to reduce input variables complexity and avoid multi-collinearity when there are many variables involved to the number of observations. It explains the maximum amount of variance with the fewest number of principal components. the input variables into principal components that are the linear combinations of the original variables, and the maximum number of components extracted always equals to the number of original variables [17-26]. Artificial Neural Networks (ANNs) are simplified computational model whose functions are similar to human brain. It is capable of curve fitting, classifying, clustering, and dynamic time series forecasting. Neural fitting tool solves an input-output fitting problem by using a two-layer feed-forward neural network with sigmoid hidden neurons and linear output neurons [27-33]. The network is trained with Levenberg-Marquardt backpropagation algorithm, and it maps between a data set of numeric inputs and a set of numeric targets. The neural fitting app selects data, create and train a network, and evaluate its performance using mean square error and regression analysis [31-39].

4.0 DISCUSSION

Correlation Matrix shows that first three PCs cumulatively explain 97.5% of the total variability, suggesting that these 3 PCs adequately explain the variation in the data. Continuous predictor standardization, subtract the mean, then divide by the standard deviation is applied on PCs values. Stepwise algorithm with candidate terms: PC1, PC2, and PC3 is processed to select the signific ant terms and construct the regression equation. Significant terms are chosen based on the significance level. Alpha-to-Enter is selected to be 0.15, greater than usual 0.05, so that it is not too difficult to enter predictors into the model. While Alpha-to-Remove is 0.15, greater than usual 0.05, so that it is not easy to remove predictors from the model. Stepwise algorithm provides the final model in equation 1. The model has R2 = 0.864, mean that 86.4% of variation in the response data can be explained by this model. Table 4 is the analysis of variance for total MSW generation, which illustrates the variation amount in data response explained by predictors. In this regression, p-value is 0.000 demonstrate that at least one of the regression coefficients is significantly different than zero. P-value of PC1 =0.000, and the only one predictor exists in the model, so PC1 is the significant predictor in this regression model.
Regression equation in uncoded units of total MSW is therefore expressed as x0 = 2276 + 0.000325 PC1. Neural network architecture with 7 inputs and 1 output is designed by choosing 1 neuron in hidden layer and other 1 neuron in output layer. Each time a neural network is trained, the results can be different because of the different initial weight and bias values and divisions of data in training, validation, and test sets. To make sure that a neural network has good accuracy, retraining several times is required. In this model, R2 is over 0.96 for the total response. The result from this network is satisfactory, so this network can be use on new inputs to predict future MSW generation. Fig. 2 shows the observed and predicted MSW from PCA-Regression and ANN Model.

4.0 CONCLUSION

Appropriate forecasting model of MSW generation is an important tool in MSW management systems and planning. Total number of residents, native people aged 15 to 59 year, total people aged 15 to 59 years, number of households, income per household, and number of tourists are considered as the influential variables since they exist with high coefficient in PC1 which is the significant term in regression equation. ANN, nonlinear model, gives high accurate result compare with regression analysis, which is a linear model. Furthermore, one neuron in hidden layer is enough to give a good result of MSW prediction. ANN model is possibly stored for further analysis under the same conditions for high percentage of accuracy. In case higher accuracy of result is needed, increasing number of neurons in hidden layer is recommended. This study demonstrates the influential variables affecting the amount of MSW generation, and offers an appropriate model to forecast MSW in Bangkok. The developed model can be used for further studies on the investigation of sustainable solutions for MSW management, and suitable technologies for Bangkok MSW disposal and power generation.

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