Modelling municipal waste generation using support vector machine, artificial neural network and deep learning

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ABSTRACT

To evaluate the urban solid waste management program, identifying the factors that affect the production of urban waste plays a vital role. Knowing the factors affecting the production of urban waste and determining the importance of each factor allows the decision-makers to take the necessary measures. The purpose of this research is to investigate the factors affecting waste production, including geographical, social, meteorological, cultural, and economic parameters, and to find their relationship with waste production. Also, finding the factors that have the greatest impact on waste production in Tehran and getting to know them more is one of the goals of this research. In this research, various factors affecting the production of urban waste are identified and the information related to these factors and how they affect the production of waste are evaluated, and the correlation of each of these factors with production waste has been obtained by using Python software and creating a heat map. Then, the quantitative modeling of urban waste in Tehran city using smart regression models, artificial neural networks, support vector machine and deep learning was discussed and the results and errors obtained from them were analyzed. Using the information sources available in domestic and reliable scientific centers as well as organizations related to this research (related specialized companies, municipalities), available studies in Iran, and some sources and studies available in reliable scientific research sites related to the subject. Abroad, it has been investigated in the field of urban waste.

KEYWORDS

Waste management, Municipal waste, Modelling, Deep learning, Waste generation, Machine learning

1. Introduction

The rapid increase in migration to megacities in developing countries, coupled with inadequate environmental infrastructure, has resulted in numerous ecological challenges. One of the most significant issues is the management of solid waste in urban areas. Urban solid waste management plays a critical role in achieving sustainable development goals. The rapid pace of urbanization, population growth, and economic development has led to the generation of substantial amounts of municipal solid waste (MSW) that require proper treatment and disposal. However, creating an effective MSW management system in megacities is challenging due to the heterogeneous nature of waste and the involvement of uncertain factors. Neglecting this issue can pose significant risks to public health [1].

The first step in designing an accurate and efficient waste management strategy is to gain a comprehensive understanding of the quantity and quality of waste from physical, chemical, and biological perspectives. This knowledge is critical for evaluating, designing, and selecting appropriate equipment for disposal, recycling, and energy recovery processes. Predicting waste generation, especially in the absence of prioritized recycling programs, is vital for determining investment requirements for machinery, storage, transfer stations, and landfill capacity. Developing reliable models that account for factors such as population changes, economic feasibility, and recycling can significantly enhance waste management strategies [2].

Traditional waste management processes are complex, nonlinear, and influenced by technical, climatic, environmental, demographic, socio-economic, and legal factors. Recently, artificial intelligence (AI) techniques have emerged as alternative computational approaches for addressing these challenges. AI models, such as Artificial Neural Networks (ANNs), expert systems, genetic algorithms, and fuzzy logic, have demonstrated efficiency in handling uncertain data, learning from experience, and managing incomplete information. For instance, ANNs are capable of classifying and predicting waste data, while fuzzy logic systems incorporate human-like cognitive and reasoning skills. Evolutionary algorithms like genetic algorithms optimize results by selecting suitable data for unforeseen conditions [3].

In the field of environmental engineering, AI has been widely implemented to address issues such as air pollution, water treatment modeling, and waste management planning. In the context of MSW management, AI models are utilized for predicting waste generation patterns, optimizing waste collection routes, selecting waste management sites, and simulating waste conversion processes. Machine learning and deep learning models have also shown significant potential in improving waste management efficiency, particularly in megacities like Tehran. This study proposes a comprehensive AI-based model for mid- and long-term waste quantification, using Tehran as a case study. The objectives include (a) developing an intelligent model for accurate waste prediction, (b) evaluating the model's performance using Tehran's waste management data, and (c) comparing the proposed deep learning algorithm with other successful AI-based waste prediction models [4].

2. Methodology

Deep learning, a specialized branch of machine learning, automates the process of feature extraction and classification from raw data. Unlike traditional machine learning, which requires manual feature selection, deep learning algorithms can automatically learn to classify data, improving their performance as more information is added. This research utilizes deep learning for quantitative modeling of urban waste generation while examining the impact of various factors.

Study Area: Tehran

Tehran, the capital of Iran, produces an estimated 800 to 850 grams of waste per resident daily, significantly exceeding global standards. Overall, only 8% of urban waste in Iran is recycled or reused, with 92% disposed of, often unsafely. Approximately 47,000 tons of waste are generated daily across the country [5, 6].

Waste Generation Modeling

This study analyzes various factors influencing waste production, including temporal (year, month, season), geographical (average temperature and rainfall), economic (GDP and income), cultural (education levels), and social (population size). Data from 1991 to 2013 were collected to assess these relationships. Effective indicators will aid in planning to reduce waste generation and improve waste management practices. The study employs artificial neural networks, regression analysis, support vector machines, and deep learning algorithms for quantitative modeling.

Predictive Methods

Artificial neural networks consist of multiple layers that process data through interconnected neurons. Support vector machines offer powerful classification capabilities by finding optimal hyperplanes for data separation. Deep learning utilizes large neural networks to classify data directly from images or text, achieving high accuracy through extensive datasets. This research will implement these models using Python and relevant libraries such as NumPy and Pandas to enhance urban waste management strategies in Tehran.

3. Results and Discussion

This study investigates the correlation between various factors influencing urban waste generation in Tehran. Hitmaps illustrate the seasonal and monthly correlations of these factors, with lighter colors indicating weaker correlations and darker colors indicating stronger ones. The analysis spans a 22-year period, categorizing the first four years as short-term, the next twelve as medium-term, and the remaining years as long-term. Findings reveal that average temperature significantly affects waste production in the short term due to seasonal changes, while rainfall has negligible impact across all periods. Gross domestic product (GDP) and population are identified as major contributors to waste generation, particularly in the long term. Notably, female population density shows a greater influence on waste production compared to males, attributed to women's role in household waste generation.

The study also highlights the importance of education level, with educated women demonstrating higher awareness regarding household waste management. Income emerges as a critical economic factor affecting waste generation over time, with higher income correlating with increased consumption and waste production. While unemployment rates affect waste generation in the short term, their impact diminishes in the long run. The presence of students in Tehran contributes significantly to waste generation, especially as many come from other cities for education.

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Subsequently, quantitative modeling of urban waste was performed using intelligent models. The results indicate that deep learning provides more accurate estimates for landfill volumes and waste collection costs compared to traditional models like regression and support vector machines. Overall, this research underscores the significance of understanding input factors and their correlations to enhance urban waste management strategies in Tehran.

4. Conclusions

This study develops a comprehensive model for monthly and seasonal waste generation using data from Tehran. It identifies various influencing factors, including temporal (year, month, season), geographical (average temperature, rainfall), economic (GDP, income), cultural (educated population, unemployment rate), and social (total population, household size, gender distribution) components. Data from 1991 to 2013 were analyzed due to administrative changes in Tehran after 2013.

The analysis reveals that effective indicators are essential for improving waste management strategies. Quantitative modeling was performed using artificial neural networks, regression analysis, support vector machines, and deep learning algorithms. Results indicate that seasonal modeling provides more accurate predictions with lower errors compared to monthly modeling. Deep learning outperformed other models in predicting waste quantities. Future research should consider newer intelligent models and optimization algorithms while exploring additional factors such as economic indicators and the impact of pandemics. The study also suggests investigating nonlinear relationships among factors for a deeper understanding of their effects on waste generation.

5. References

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