Estimation of Landfill Volume of Municipal Solid Waste Quantity in India using Artificial Neural Network

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Abstract

This study examines the application of Artificial Neural Networks (ANN) to predict landfill requirements for solid waste disposal. As urbanization and population growth accelerate, effective waste management becomes extensively critical. Traditional landfill forecasting methods often struggle with the non-linear and complex nature of waste generation models. ANN, known for its ability to model non-linear relationships, is used to improve prediction accuracy. We developed an ANN model using historical data on solid waste generation, population growth, economic indicators, and other relevant factors. The model was trained and validated using a large metropolitan data set, ensuring that it captures variation and trends in waste generation. The results show that the ANN model significantly outperforms traditional linear regression methods and provides more accurate and reliable predictions about landfills. The sensitivity analysis revealed that population growth and economic activity are the most influential factors in forecasting waste production. The study says ANN is an effective tool for urban waste management planning and helps to ensure adequate landfill and sustainable waste management.

Keywords

Artificial neural network, solid waste disposal, landfill prediction, waste management, urbanization, predictive modeling.

Introduction

Municipal solid waste (MSW) is described as solid and semi-solid garbage generated by a country or states by daily basis. Generation and disposal of municipal solid waste is one of the biggest challenges in India which requires effective management of solid waste. This is a complex issue that requires careful consideration and innovative solutions. India is the 10th biggest country generates municipal solid waste from different states and cities[1]. The municipal solid waste mainly generates from Residential, Commercial, Industrial, Institutional, Agricultural, Construction, Demolition. Municipal solid waste generation is based on Population of country. Municipal solid waste is highly effect to climate like water pollution, air pollution and mainly land pollution and creates health and other issues. Generally municipal solid waste quantity expresses or shows in (Kg/capita/day) or (MT/D). For solid waste Generation or solid waste disposal Landfill area calculation is based on population of state or city, and daily basis solid waste generation.

Today, the main challenging task consists of the sequential stages of collection, transportation, and disposal of municipal solid waste. Solid waste management is significant problem since increasing population and increasing consumer demand is directly relating to increase in solid waste quantity each year. Municipal solid waste highly impact on the environment, legal, economic aspects. These problems arise from lack of data and information and the adoption of advanced modelling techniques. Today smart cities are adopting advanced techniques like Artificial Neural Network (ANN) by predicting waste generation and managing solid waste required area for dumping the garbage. ANN gets high attention because of easy to use and good performance network system. Artificial Neural Network gives precise results of prediction of generation of solid waste rate.

Study area

India is the diversify country. India is the 2nd largest country in Asia based on area which is 3,287,263 square kilometers. India Co-ordinates are 20.5937° N, 78.9629° E. There are 28 states and 4000 cities and towns in India[3]. There are 1874 municipalities with the population of 141.72 crores on Average. there are 3100 landfill presents for dumping solid waste in across India.

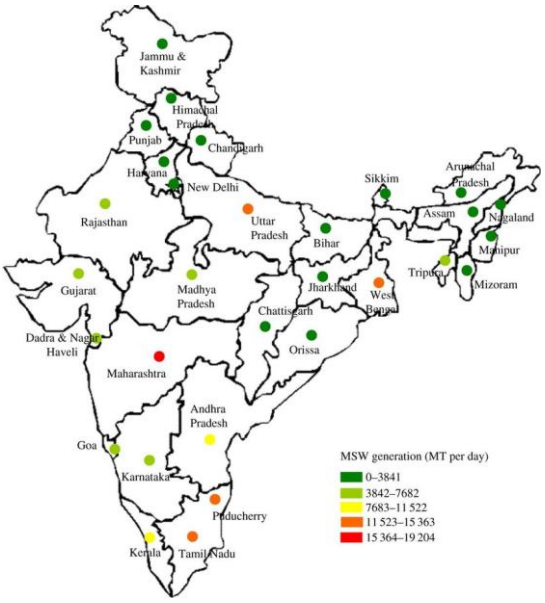

Figure 1: MSW Generation in India[9]

Artificial Neural Network

An Artificial Neural Network (ANN) is a computer programming crafted after biological neural networks, such the human brain. The artificial neural network is the main element in artificial intelligence system. Artificial neural networks are constructed of artificial neurons. These units are grouped into layers, which together form the framework of the whole artificially generated neural network. A layer may consist as little as a couple units or as many as millions of units, based on the complexity required for neural networks to detect hidden patterns in the data set. In general, a neural network is made up of three layers: input, output, and hidden[5]. The input layer collects inputs from the outside world that the neural network is supposed to analyze or learn. This data is passed via several layers that are hidden, which transform the input into beneficial data for the output layer. Furthermore, the output layer constructs an artificial neural network's response to the given input data. The majority of neural networks have units that link between layers. Each of these links has a weighting system that determines the influence of one unit on another. As data changes from one unit to another, the neural network gains increasing knowledge about the data, ultimately culminating in the response from the output layer[6]. The artificial neural network (ANN) is capable of performing complex calculations in a timely manner. The artificial neural network encompasses the interconnection of multiple neurons and hidden layers. Uses of ANN: Artificial neural networks find application in social media, such as Facebook's "People You May Know" feature, to propose potential real-life friends based on profiles, interests, and connections. Facial recognition

serves as another application, linking reference points on an individual's face to existing databases. E-commerce platforms like Amazon and Flipkart employ personalized marketing strategies to recommend products based on previous browsing behaviors. This technology extends to modern marketing sectors, including bookstores, movie services, and hospitality websites, employing artificial neural networks to tailor campaigns accordingly.

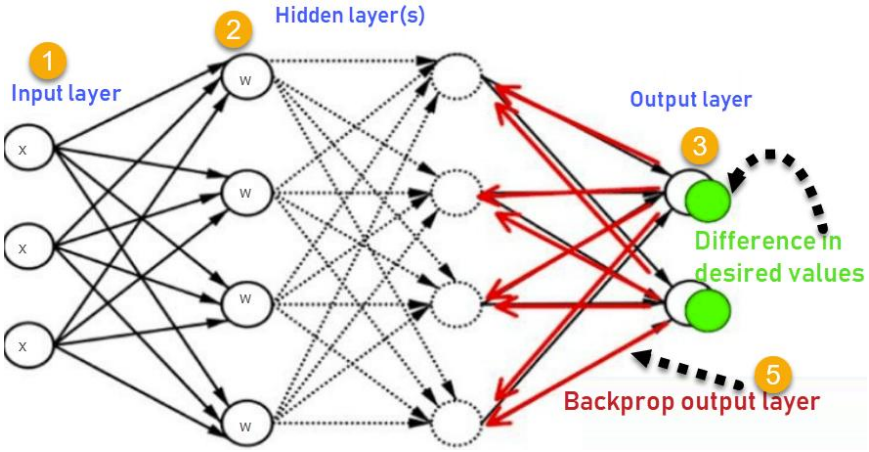

Figure 2: **Typical layout of artificial neural network**

Methodology

To estimate the landfill extent of municipal solid waste (MSW) the use of Artificial Neural Networks (ANN) in India, a scientific technique is needed that mixes statistics collection, version education, validation, and prediction[4]. Here is a step-by-step approach:

1. **Data Collection:**

Gather applicable and great statistics for the education and validation of the ANN version. The key statistics reasserts may include:

- **Historical MSW Generation Data:** Collection of every day or month-to-month waste era statistics from municipalities.
- **Waste Composition**: Breakdown of organic, recyclable, and inert waste types.
- **Population Data:** City-sensible populace and demographics influencing waste era.
- **Landfill Data:** Existing landfill potential, area, height, and extent statistics from municipal authorities.
- **Waste Collection Efficiency:** Information on the gathering methods, performance rates, and recycling efforts.

- **Socioeconomic Data:** Urbanization, earnings levels, and life-style elements influencing waste era.

Sources: Local municipalities, Central Pollution Control Board (CPCB), or Ministry of Housing and Urban Affairs (MOHUA).

2. Preprocessing the Data:

- **Normalization/Scaling:** Waste statistics can range significantly in magnitude. Scale the enter features (e.g., waste extent, populace) so that they have got a comparable range, frequently among zero and 1, to assist the ANN carry out better.
- **Data Cleaning:** Remove outliers or lacking values from datasets to make certain easy education.
- **Segmentation:** Break the statistics into education, validation, and trying out sets (typically 70%-15%-15%).

3. Feature Selection:

- **Independent Variables (Inputs):** Waste era rates, populace size, waste composition percentages, socioeconomic elements, and recycling rates.
- **Dependent Variable (Output):** The expected landfill extent required over a period.

4. Model Selection and ANN Design:

- **Network Architecture:** Use a Multi-Layer Perceptron (MLP) with an enter layer, hidden layers, and an output layer. The quantity of hidden layers and neurons may be optimized through experimentation.
- **Activation Functions:** Use activation features like the neural network employs ReLU (Rectified Linear Unit) activation functions in its hidden layers and a linear activation function in the output layer to make certain correct non-stop variable predictions.
- **Loss Function:** Use Mean Squared Error (MSE) because of the loss characteristic because that is a regression problem.
- **Model Training:** Train the ANN the use of the accrued and reprocessed statistics. During education, the version learns to map the enter features (waste era statistics, populace, etc.) to the goal output (landfill extent).

- **Backpropagation:** Adjust the weights and biases the use of backpropagation to reduce the loss characteristic over iterations (epochs).

5. Validation and Testing:

- After education, validate the version with the validation set to fine-song hyper parameters consisting of the gaining knowledge of rate, quantity of layers, and neurons in every layer.
- Test the skilled ANN at the check set to assess its overall performance the use of metrics consisting of Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and R^2 score.

6. Model Deployment:

- Once the ANN version gives first-rate predictions, it is able to be deployed for forecasting landfill volumes. The version can expect the destiny landfill necessities primarily based totally on forecasted waste era patterns.

7. Scenario Analysis:

The ANN version may be used for state of affairs evaluation:

- **Population Growth Projections:** Analyze the effect of populace increase on landfill necessities.
- **Waste Management Strategies:** Evaluate how distinctive waste diversion strategies (recycling, composting) lessen landfill extent.

8. Software and Tools:

- Python with libraries like TensorFlow or PyTorch for constructing and educating the ANN.
- **Data Analysis Tools:** Pandas, NumPy, and Matplotlib for statistics processing and visualization.
- **GIS Software (optional):** For spatial evaluation of landfill site capacity and waste distribution patterns.

9. Validation Against Real-global Data:

- Validate the predictions in opposition to real landfill extent statistics from towns in India to make certain the version's reliability and accuracy.

Experimental Work

This study is to predict landfill area required for municipal solid waste dumping in 2026. Rapid increase in population rate led to higher municipal waste generation. Improper waste management system are major reasons for requirement of larger landfill areas. This paper discusses prediction the landfill area required based on waste generation and treatment given.

An ANN is composed of three layers: the input layer, the hidden layer, and the output layer. In this research the data has been taken from Central Pollution Control Board (CPCB) website[5]. The data is given in APPENDIX-1. And the data is year 2020-21. Various states of India have been taken for the study. Here, waste generation rate of a particular state, amount of waste treated and landfilled waste data has been collected and trained on ANN.

Waste generation data: Past data on the amount of waste generated per day, month, or year.

Demographics: Information about the population of the landfill, as waste production is often correlated with population size.

Economic data: economic indicators such as GDP, as economic activity affects waste production.

Seasonal and Weather Information: Seasonal trends and weather conditions that may affect waste production.

Information on Operational Landfills: Information on landfill capacity, usable area and operational aspects.

Data pre-processing Prepare the collected data for ANN training: Normalization: Scale the data to an appropriate range for the ANN (typically between 0 and 1 or -1 and 1).

Missing values: Handle missing data using interpolation, averaging, or other appropriate methods. Selection of Characteristics: Identify the most important characteristics of the model (e.g., population size, economic indicators, seasonality).

Model design the ANN architecture: Input layer: The quantity of neurons is equivalent to the number of inputs. Hidden layers: Specify the quantity and dimensions of hidden layers. Common practices involve experimenting with various configurations (e.g. one to three hidden layers with differing numbers of neurons). Output layer typically consists of a single neuron that signifies the predicted volume of garbage. To summarize, data from 35 states in India is compiled. Following data preprocessing and partitioning, we formulated an ANN with: Input layer: 3 neurons (denoting 3 input functions) Hidden layers: 3 layers containing 6 Hidden Nodes. Output layer: We trained the model utilizing a learning rate of 0. 01, comprising a set of 35 values. Utilizing this model, we subsequently projected the Landfill area necessary for

the disposal of municipal solid waste in 2026, which assisted in the planning of landfill management capacity and the adjustment of operations.

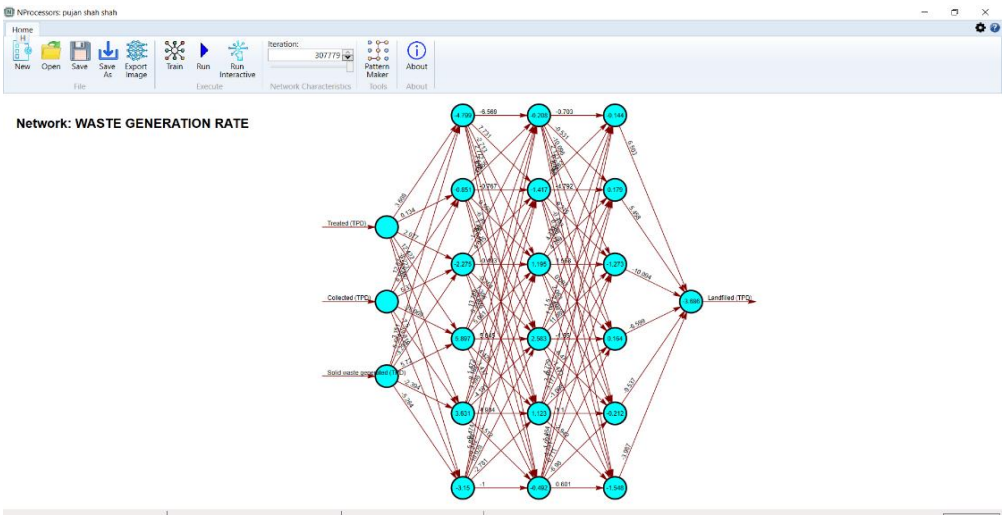

Figure 3: Artificial Neural Network Training for Future Prediction of Landfill.

Results and Discussion

In India 59 cities 35 metro cities and 24 state. today India is the largest country in population. Municipal solid waste Management is biggest task for India in today's time. The CPCB 2021 municipal solid waste data based on this prediction has been performed on NProcessors software for the next 2 years[8]. Artificial Neural Network was used to predict landfill on depending upon the solid waste Generated and Treated the solid waste. The current error is 0.019 and the network type is Feed forward back propagation. After applying Artificial Neural network, we get the predicted values. And then plot the Predicted Landfill values in scatter graph and get R^2 (Co-officiant of Regression) value is 0.8355.

Landfill (TPD)	**Predicted Landfill (TPD)**
27.5	61.863
51.55	62.592

Table 2: Predicted Value from ANN

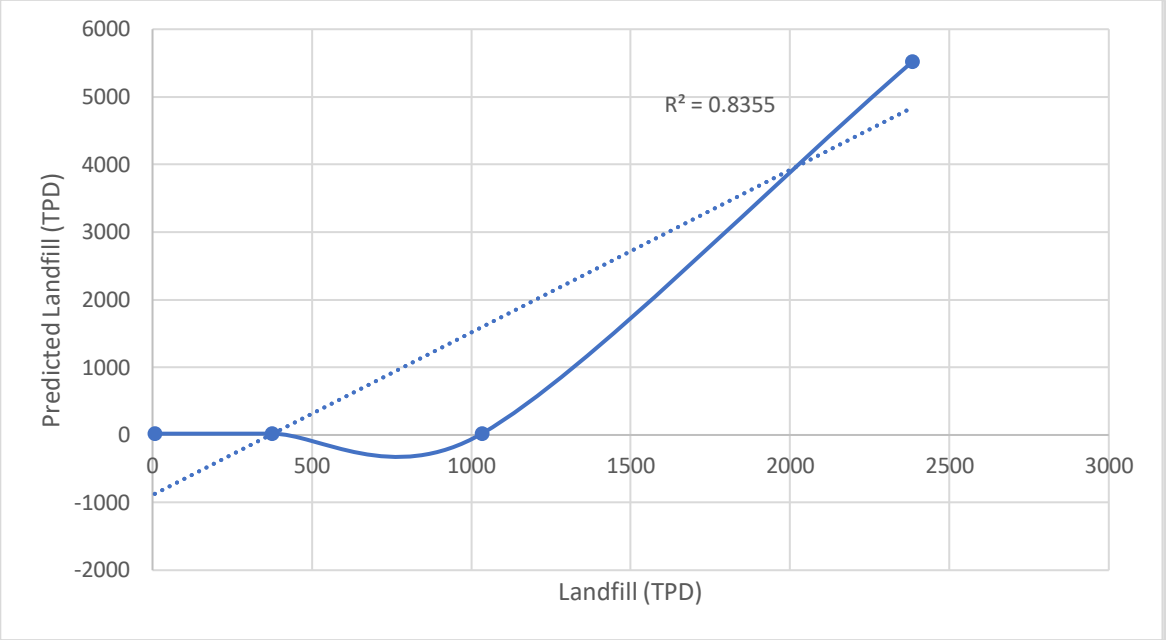

Figure 4: Graph of R^2 (Co-officiant of Regression)

Conclusion

In conclusion, an experimental approach to using ANN for landfill solid waste forecasting involves careful data processing, model design, training, evaluation, and deployment. When properly implemented, it provides accurate forecasts that can significantly improve landfill management and planning. Overall, the application of ANNs to MSW landfill forecasting represents a forward-looking approach that can significantly promote sustainable waste management and help municipalities manage waste more efficiently while minimizing environmental impact.

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APPENDIX – 1[7]

SI No	State	Solid waste generated (TPD)	Collected (TPD)	Treated (TPD)
1	Andhra Pradesh	6898	6829	1133
2	Arunachal Pradesh	236.51	202.11	0
3	Assam	1199	1091	41.4
4	Bihar	4281.27	4013.55	0
5	Chhattisgarh	1650	1650	1650
6	Goa	226.87	218.87	197.4
7	Gujarat	10373.79	10332	6946
8	Haryana	5352.12	5291.41	3123.9
9	Himachal Pradesh	346	332	221
10	Jammu & Kashmir	1463.23	1437.28	547.5
11	Jharkhand	2226.39	1851.65	758.26
12	Karnataka	11085	10198	6817
13	kerala	3543	964.76	2550
14	Madhya Pradesh	8022.5	7235.5	6472
15	Maharashtra	22632.71	22584.4	15056.1
16	Manipur	282.3	190.3	108.6
17	Meghalaya	107.01	93.02	9.64
18	Mizoram	345.47	275.92	269.71
19	Nagaland	330.49	285.49	122
20	Odisha	2132.95	2097.14	1038.31
21	Punjab	4338.37	4278.86	1894.04

22	Rajasthan	6897.16	6720.476	1210.46
23	Sikkim	71.9	71.9	20.35
24	Tamil Nadu	13422	12844	9430.35
25	Telangana	9965	9965	7530
26	Tripura	333.9	317.69	214.06
27	Uttarakhand	1458.46	1378.99	779.85
28	Uttar Pradesh	14710	14292	5520
29	West Bengal	13709	13356	667.6
30	Andaman and Nicobar Islands	89	82	75
31	Chandigarh	513	513	69
32	DDDNH	267	267	237
33	Delhi	10990	10990	5193.57
34	Lakshadweep	35	17.13	17.13
35	Puducherry	504.5	482	36

Table 1: - Solid waste generation and Treated data in (TPD) (data= Year- 2020-21)[2,3]

Retrieved from https://cpcb.nic.in/uploads/MSW/MSW_AnnualReport_2020-21.pdf

Glossary

Solid Waste Management- Typical steps to be followed from waste generation to disposal in a scientific manner.

Landfill- An ultimate location for disposal of solid waste in a scientific way without polluting other natural resources.

Artificial Neural Network- A programming language of series of networks which behaves like human brain.

Landfill prediction- Forecasting of future space requirement for disposal of solid waste into the ground.