Prediction of Municipal Solid Waste with RBF Net Work- A Case Study of Eluru, A.P, India

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***Abstract*—This paper is an attempt made to estimate the quantity of Municipal solid waste that can be generated in the ELURU city, A.P, INDIA from 2010 to 2026. The prediction of municipal solid waste generation plays an important role in solid waste management. Yet achieving the anticipated prediction accuracy with regard to the generation trends facing many fast growing regions is quite challenging. In addition to population growth and migration, underlying economic development, household size, employment changes, and the impact of waste recycling would influence the solid waste generation interactively. The development of a reliable model for predicting the aggregate impact of economic trend, population changes, and recycling impact on solid waste generation would be a useful advance in the practice of solid waste management. The four input variables considered in the ANN model to predict MSW in the study area are Population of MCE, MSW generated at MCE, Percentage of urban population of the nation and GDP per capita of the nation. A radial basis function network is an artificial neural network that uses radial basis functions as activation functions. It is a linear combination of radial basis functions. They are used in function approximation, time series prediction, and control. In the absence of adequate past data on waste generation rates,it is extremely difficult to decide upon the methodology to make any kind of projections for the future.Hardly any primary survey studies have been made in the study area,which indicate the actual waste quantam generated. As a result,except for data points from 1961 to 2001 population based on census , Municipal solid waste generated at MCE from 1961 to 2001 and 2009 based on the data collected from the MCE, urban population percentage in the total population as per census for the above period based on national scenario and the year wise data of GDP per capita on the national scenario,there is no data available on the basis. The estimates of waste quantum for period from 2010 to 2026,shows that if the growth of population, growth of percentage increase in per capita waste generation, growth of urban population and future estimate of GDP per capita are considered as per the nation projections, the MSW in the study area can be expected by radial basis function ANN model using MAT Lab Version 7.8.0.347 as around 39,670 MT per year in MCE by 2026.**

***Index Terms*—Municipal Solid Waste (MSW), Artificial Neural Net Works (ANN), Radial Basis Function (RBF), Prediction.**

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I. Introduction

India is one of the fastest growing economies in the world today. Increasing prosperity and standard of living of millions of people will increase consumption of energy and consumer goods. Concurrently, this growth will likely put a strain on the environment and on the availability of natural resources. Already, India has 16.8% of the world's population (est. 2006) and only 2.2% of the world's total land area. [1]. The amount of waste generated in a region or country is directly proportional to economic growth and consumption levels. On a per capita basis, low-income countries generally consume fewer goods and hence generate less waste than developed countries. Low-income countries also generally use less recyclable materials, especially in packaging. Larger cities tend to produce higher amounts of waste per capita than smaller ones because per capita incomes and consumption are higher in urban areas. [2, 3]. Waste generation in India is expected to increase rapidly in the future. As more people migrate to urban areas and as incomes increase, consumption levels are likely to rise, as are rates of waste generation. This has significant impacts on the amount of land that is and will be needed for disposal, economic costs of collecting and transporting the waste, and the environmental consequences of increased MSW generation levels.

It is estimated that the amount of waste generated in India will increase at a per capita rate of approximately 1-1.33% annually. [4] A World Bank publication reports that the waste generation rate in urban areas of India will be approximately 0.7 kg/person/day in 2025, which is roughly four to six times higher than it was in 1999. [2].

The artificial model of the brain is known as ANN (Sahin, *et al.,* 2005). [29] Ann's were first introduced in the 1940s (McCulloch & Pitts, 1943) [30]. Interest grew in these tools until the 1960s when Minsky and Papert showed that networks of any practical size could not be trained effectively (Minsky & Papert, 1969) [31]. It was not until the mid-1980s that Ann's once again became popular with the research community when Rumelhart and McClelland rediscovered a calibration algorithm that could be used to train networks of sufficient sizes and complexities to be of practical benefit (Rumelhart & McClelland, 1986) &(Ashwini Bapat,2010). [32, 33].

There has been a significant increase in MSW (municipal solid waste) generation in India in the last few decades. This is largely because of rapid population growth and economic development in the country. Solid waste management has become a major environmental issue in India. The per capita of MSW generated daily, in India ranges from about 100 g in small towns to 500 g in large towns. Although, there is no national level data for MSW generation, collection and disposal, and increase in solid waste generation, over the years, it can be studied for a few urban centres. For example, the population of Mumbai grew from around 8.2 million in 1981to 12.3 million in 1991, registering a growth of around 49%. On the other hand, MSW generated in the city increased from 3 200 tones per day to 5 355 tones per day in the same period registering a growth of around 67% (CPCB2000). This clearly indicates that the growth in MSW in urban centres has outpaced the population growth in recent years. This trend can be ascribed to changing lifestyles, food habits, and change in living standards. MSW in cities is collected by respective municipalities and transported to designated disposal sites, which are normally low lying areas on the outskirts of the city. The limited revenues earmarked for the municipalities make them ill-equipped to provide for high costs involved in the collection, storage, treatment, and proper disposal of MSW. As a result, a substantial part of the MSW generated remains unattended and grows in the heaps at poorly maintained collection centres. The choice of a disposal site also is more a matter of what is available than what is suitable. The average collection efficiency for MSW in Indian cities is about 72.5% and around 70% of the cities lack adequate waste transport capacities (TERI 1998). The in sanitary methods adopted for disposal of solid wastes is, there fore, a serious health concern. The poorly maintained landfill sites are prone to groundwater contamination because of leachate production. Open dumping of garbage facilitates the breeding for disease vectors such as flies, mosquitoes, cockroaches, rats, and other pests (CPCB 2000).

A. Description of Town

Eluru, previously known as Helapuri and has a rich cultural and political history. It was a part of Buddhist Kingdom called Vengi. During the Chalukyas (700 AD – 1200 AD), Eluru was a province. Later on Eluru remained a part of Kalinga Empire. During division of Northern Circars into district, Eluru made a part of Machilipatnam district. Later it was included in the Godavari district in 1859. Subsequently, Eluru made part of Krishna district. Finally in the year 1925, West Godavari District was formed with Eluru as its headquarters. Eluru town is situated at 16.7^0 N latitude and 81.1^0E longitude on the Kolkata – Chennai National Highway (NH5). Eluru was a selection grade municipality of Andhra Pradesh. It has been upgraded to Municipal Corporation on 09.04.2005. The area of Eluru Municipal Corporation is 14.55 Sq.km with a population of 1, 90,062 as per 2001 Census. It would be seen that during the last decade Eluru experienced a negative population growth.

B. Artificial Neural Network

An artificial neural network (ANN), usually called neural network (NN), is a mathematical model or computational model that is inspired by the structure and/or functional aspects of biological neural networks. A neural network consists of an interconnected group of artificial neurons, and it processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. Modern neural networks are non-linear statistical data modeling tools. They are usually used to model complex relationships between inputs and outputs or to find patterns in data.

C. Radial Basis Function (RBF) Network

A radial basis function network is an artificial neural network that uses radial basis functions as activation functions. It is a linear combination of radial basis functions. They are used in function approximation, time series prediction, and control.

Radial basis functions are powerful techniques for interpolation in multidimensional space. A RBF is a function which has built into a distance criterion with respect to a center. Radial basis functions have been applied in the area of neural networks where they may be used as a replacement for the sigmoid hidden layer transfer characteristic in multi-layer perceptions. RBF networks have two layers of processing: In the first, input is mapped onto each RBF in the 'hidden' layer. The RBF chosen is usually a Gaussian. In regression problems the output layer is then a linear combination of hidden layer values representing mean predicted output. The interpretation of this output layer value is the same as a regression model in statistics. The Net work architecture is shown in Fig.1

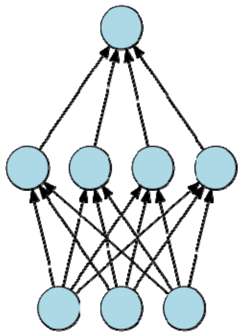


Fig.1, Network architecture

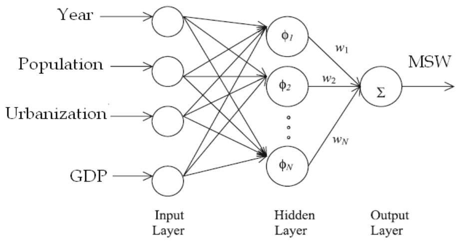
This network predicts the MSW for a group of Years { f } GDP { v } Urbanization { d } and Population { a } The output of the RBF neural network is Calculated according to:

$$\text{MSW} = \sum_{k=1}^{N} w_k \phi_k \left(\|x - c_k\|_2 \right)$$

where $\boldsymbol{x}$ = {f, *v*, *d*, *a*} *T* is the input vector, *φk(.)* is the processing function of the *k*th node in the hidden layer, _._2 denotes the Euclidean norm, *wk* are weights associated with the *k*th node in the hidden layer, the output node, *N* is the number of neurons in the hidden layer, and ***ck*** are the RBF centers in the input vector space. For each neuron in the hidden layer, Euclidean distances between its associated center and the input to the network are calculated. The output of the neuron in a hidden layer is a nonlinear function of the distance. Finally, the output of the network is calculated as a weighted sum of the hidden layer outputs. The processing function used in this work is a Gaussian function of the following form:

$$\Phi(x) = \exp\ (-x2/\sigma 2)$$

where parameter σ controls the "width" of the radial basis function and is commonly referred to as the spread parameter.



A typical RBF neural network architecture

It can be seen that there are two set of parameters governing the mapping properties of the radial basis function neural network: the weights ***wk*** and the centers ***ck.*** The simplest form of RBF neural network is one with a fixed center, chosen in a random manner as a subset of the input dataset. Once the centers are chosen, the output of the network to the input vectors in the training data set can be calculated by:

$$\mathsf{MSW} = \sum_{k=1}^{N} w_k \phi_k \left(\left\| x^{(p)} - c_k \right\|_2 \right),\ p = 1, 2, \ldots, P$$

where P is the total number of the training pairs and the bracketed superscript on the input and output indicates the pair number. The weights ***wk*** can be adjusted by a multiple linear regression procedure so that sum squared error between the predicted surface roughness values and the experimental values are minimized.

II. Literature Review

The prediction of municipal solid waste generation plays an important role in a solid waste management. Yet achieving the anticipated prediction accuracy with regard to the generation trends facing many fast growing regions is quite challenging. In addition to population growth and migration, underlying economic development, household size, employment changes, and the impact of waste recycling would influence the solid waste generation interactively. The development of a reliable model for predicting the aggregate impact of economic trend, population changes, and recycling impact on solid waste generation would be a useful advance in the practice of solid waste management.Neural networks represents a promising technology with a wide scope for potential applications. They have received increasing attentions in time series prediction [5, 6, 7, 8, 9, 10]. There is growing interest in using neural networks to forecast the future changes in prices of stocks, exchange rates, commodities, and other financial time series. The planning of municipal solid waste management systems (MSWMS) to satisfy increasing waste disposal and treatment demands is often subject to a variety of impact factors, such as collection technique to be used, service policy to be implemented, and management facilities to be adopted[11,12]. Quantity of prediction of municipal solid waste (MSW) is crucial for the planning of MSWMS, and the development of a reliable model (such as data-driven models) for this purpose would be a useful advance in the practice of MSWMS. These models are called data-driven models. Two of the data-driven models are adaptive neuro-fuzzy inference system (ANFIS) and artificial neural network (ANN) models. ANN models can be modeled complex, and nonlinear events that use this model are successful in MSWMS [11, 13, and 14]. Jalili and Noori [15] used feed-forward neural network to predict the weekly WG in Mashhad, Iran. Karaca and Özkaya [16] used ANN to control leachate generation rate in landfills.

Both planning and design of solid waste management systems require accurate prediction of solid waste generation. Conventional forecasting of solid waste generation frequently uses demographic and socioeconomic factors in a per-capita basis. The per-capita coefficients may be taken as fixed over time or they may be projected to change with time. Grossman [17] extended such considerations by including the effects of population, income level, and dwelling unit size in a single linear equation model. Niessen [18] conducted similar estimates by providing some other extensive variables characterizing waste generation. Chang, et al. [19] further applied geometric lag econometric analysis, incorporating related socioeconomic or demographic factors simultaneously over time, for the forecasting of solid waste generation in Taiwan.

The decision makers have been constantly looking for innovative and forward-looking solutions to address the issue of forecasting the quantities of municipal solid waste [20, 21, 22, 23, 24,]. A number of researchers have attempted forecasting of the composition of solid waste. Gupta et al. (1998)[25] have projected quantity and characteristics of solid waste for year 2025 using subjective judgment based on a single factor, i.e., Gross Domestic Product (GDP) of the nation. However, it should be noted that the quantitative relationship between waste characteristics and GDP was not been established and a subjective judgment was used for prediction. Khan and Burney (1989)[26] have established the influence of per capita income, population density, persons per house, GDP and population on the composition of the solid waste using linear regression. World Bank (1999) and Buenrostro et al [27, 28] have reported relationship between solid waste composition and socioeconomic factors of community using expert judgments based on secondary data.

III. Methodology

The four input variables considered in the ANN model to predict MSW are 1. Population of MCE 2. MSW generated at MCE 3. Percentage of urban population of the nation and 4. GDP per capita of the nation.

A. Population

The population data collected from EMC as per census of India is shown below. As per the report of technical group on population projections constituted by the national commission on population to the office of the Registrar general & Census commissioner of India, May 2006 the population growth in India from 2001 to 2026 shall have a growth of 36% in 25 years at a rate of 1.2% of annum. This growth rate is considered in the ANN model from 2001 to 2026 to predict the MSW generation. The population of year wise from 1961 to 2001 is obtained from the best fit curve equation shown below in Fig.2.

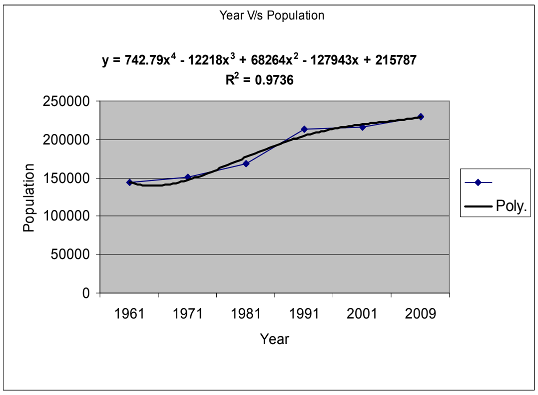


Fig.2, Best fit curve of year V/s Population

B. . Municipal Solid Waste in MT

The MSW data collected from EMC as per the office records is shown below. It is estimated that the amount of waste generated in India will increase at a pr capita rate of approximately 1.33% annually is considered for estimate of MSW from the year 2009 to 2026. The MSW of year wise from 1961 to 2009 is obtained from the best fit curve equation shown below in Fig.3.

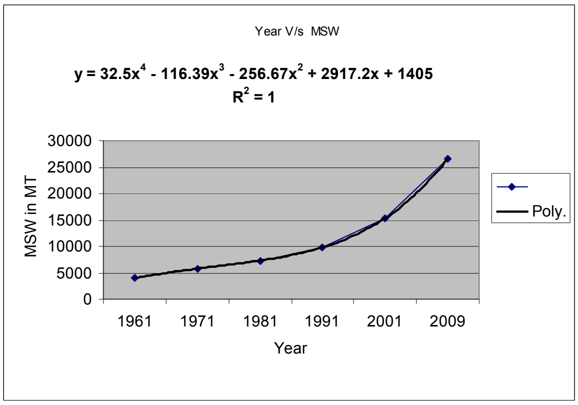


Fig.3, Best fit curve of year V/s MSW

C. Effect of Urban Population Growth on MSW Generation in India

India has historically been an agricultural economy, with the majority of people living in rural areas engaged in the agricultural sector. However, with an expanding service and manufacture driven economy, urban areas are seeing unprecedented growth. According to 2001 census, around 27.8% of India's population lives in urban areas.(census 2001) and the % of urban population of India is extracted from census India available online are shown below is used in the proposed ANN model to predict MSW. The % of urban population for India will increase to 38.2% by 2026 in 25 years. This growth rate is considered in the ANN model from 2001 to 2026 to predict the MSW generation. The % of urban population year wise from 1961 to 2001 is obtained from the best fit curve equation shown below in Fig.4.

D. Gdp Per Capita

The gross domestic product (GDP) or gross domestic income (GDI) is the market value of all final goods and services produced within a country in a given period of time. It is often positively correlated with the standard of living, alternative measures to GDP for that purpose. Gross domestic product comes under the heading of national accounts, which is a subject in macroeconomics.

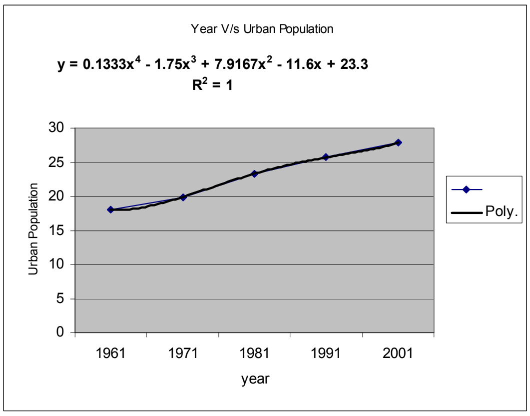


Fig.4, Best fit curve of year V/s MSW

E. Standard of living and GDP

GDP per capita is not a measurement of the standard of living in an economy. However, it is often used as such an indicator, on the rationale that all citizens would benefit from their country's increased economic production. Similarly, GDP per capita is not a measure of personal income. GDP may increase while real incomes for the majority decline. The major advantage of GDP per capita as an indicator of standard of living is that it is measured frequently, widely, and consistently. It is measured frequently in that most countries provide information on GDP on a quarterly basis, allowing trends to be seen quickly. It is measured widely in that some measure of GDP is available for almost every country in the world, allowing inter-country comparisons. It is measured consistently in that the technical definition of GDP is relatively consistent among countries.

The major disadvantage is that it is not a measure of standard of living. GDP is intended to be a measure of total national economic activity which is a separate concept.

There is a direct link between GDP and MSW generation. A number of studies have found that the higher the household income and standard of living, the higher the amount of MSW generated. The World Bank study summarized the progression of MSWM practices in a country as its income increases.

The GDP per capita of India at current prices is available on line from World Bank World development indicator. GDP per capita are shown below is used in the proposed ANN model to predict MSW. The GDP per capita projection for India will increase at the rate of 5.4% in the coming years is considered in ANN model for prediction of MSW in future.

IV. Results

The output data of predicted MSW at MCE is obtained with the RBF network on MAT LAB, Version: 7.8.0.347, 32-Bit (win32) as shown in Table1.

Fig.5, illustrates the estimates of waste quantum for period from 2010 to 2026,shows that if the growth of population, Groth of percentage increase in per capita waste generation, growth of urban population and future estimate of GDP per capita are considered as per the nation projections, the MSW in the study area can be expected by radial basis function ANN model around 39,670 MT per year by 2026 in MCE. Fig.6, shows the graph between % error between the RBF model and MSW gereration in MT by extrapolation per year at MCE.

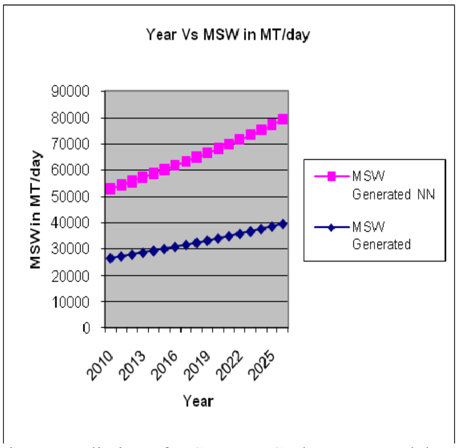


Fig. 5. Prediction of MSW at MCE by RBF Model

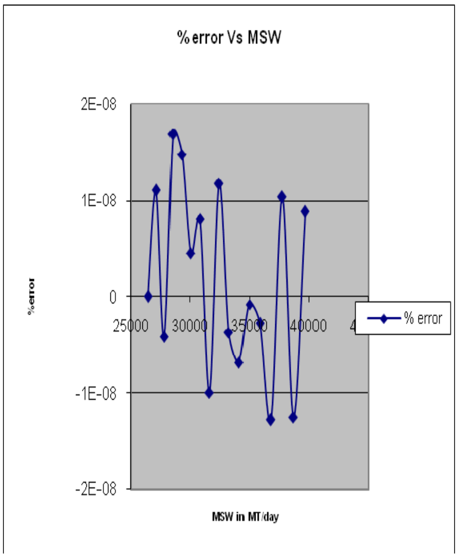


Fig. 6. % of Error Vs MSW by RBF

It is important to mention here that the above projection of MSW is based on the national projections of data and the local Fig.6 on MSW also depend upon food habits of people and the degree of commercial and industrial activity in MCE by 2026.

TABLE1. Predicted MSW at MCE is Obtained with the RBF Network

Year	MSW projection by ANN model in MT	% Error
2010	26461.5	0
2011	27140.56189	-3E-06
2012	27837.05005	1.17E-06
2013	28551.41166	-4.8E-06
2014	29284.10541	-4.3E-06
2015	30035.60174	-1.3E-06
2016	30806.38316	-2.5E-06
2017	31596.94458	3.14E-06
2018	32407.79358	-3.8E-06
2019	33239.45081	1.23E-06
2020	34092.45024	2.32E-06
2021	34967.33956	2.83E-07
2022	35864.68052	9.94E-07
2023	36785.04928	4.7E-06
2024	37729.03677	-3.9E-06
2025	38697.24913	4.84E-06
2026	39690.30799	-3.5E-06

V. Conclusions

In the absence of adequate past data on waste generation rates,it is extremely difficult to decide upon the methodology to make any kind of projections for the future.Hardly any primary survey studies have been made in the study area,which indicate the actual waste quantam generated. As a result,except for data points from 1961 to 2001 population based on census , Municipal solid waste generated at MCE from 1961 to 2001 and 2009 based on thedata collected from the MCE, urban population percentage in the total population as per census for the above period based on national scenario and the year wise data of GDP per capita on the national scenario,there is no data available on the basis .As per the report of technical group on population projections constituted by the national commission on population to the office of the Registrar general & Census commissioner of India, May 2006 the population growth in India from 2001 to 2026 shall have a growth of 36% in 25 years at a rate of 1.2% of annum. This growth rate is considered in the ANN model from 2001 to 2026 to predict the MSW generation of future projection. The population of year wise from 1961 to 2001 is obtained from the best fit curve equation. It is estimated that the amount of waste generated in India will increase at a per capita rate of approximately 1.33% annually is considered in the ANN model from 2010 to 2026 to predict the future generation of MSW. The MSW of year wise from 1961 to 2009 is obtained from the best fit curve equation. The % of urban population for India will increase to 38.2% by 2026 in 25 years. This growth rate is considered in the ANN model from 2001 to 2026 to predict the MSW generation. The % of urban population year wise from 1961 to 2001 is obtained from the best fit curve equation. The GDP per capita projections for India estimate an increase at the rate of 5.4% in the coming years is considered in ANN model for prediction of MSW in future

The Municipal corporations being the responsible authority in India for MSW management,in addition to a wide range of responsibilities related to health and sanitatation have not been very effective as far as MSW services are concerned and MCE is not an exception to this scenario. Collection,Transportation and disposal of MSW lack interms infrastructure,maintanance and upgradation of resources in municipalities.

Experience indicates the estimation of solid waste generation is very crucial for the subsequant system planning of MSW management in MCE from both short and long term perspective.How ever a complete record of solid waste generation and composition is not present at MCE. The central idea in this work is to utilize radial basis function approach of Atificial Neural Net Works model so as to minimize the discrepency between the predicted values and observed values of MSW. A case study of future solid waste generation in MCE demonstrates the application potential of such an approach.

REFERENCES

[1] CIA. 2007. The World Fact book 2007, On-line. Available at https://www.cia.gov/cia/publications/factbook/index.html, accessed January 29, 2007.

[2] World Bank. 1999. What a Waste – Solid Waste Management in Asia, Urban Development Sector Unit, East Asia and Pacific Region, May 1999.

[3] Ministry of Urban Development. 2000, Government of India, Solid Waste Management Manual.

[4] Eduard V, My T, Levin A, Bulato Rudolfo A. Bos. World Population Projections, 1992–1993Edition: Estimates and Projections with Related Demographic Statistics. The World Bank: John Hopkins, 1993.

[5] Leung M T, Chen A S, Daouk H, Forecasting exchange rates using general regression neural networks, Computers & Operation Research, 27 (4), pp1093-1110, 2000.

[6] Cao L, Gu Q, Dynamic support vector machines for nonstationary time series forecasting, Intell Data Anal 6, pp.67–83, 2002.

[7] Cao LJ, Tay Francis EH, Financial forecasting using support vector machines, Neural Computing & applications, 10(2), pp.184-192, 2001.

[8] Virili F, Freisleben B, Neural network model selection for financial time series prediction, Compute Stat,16(3), pp.451-463 ,2001.

[9] Qai M, GP Zhang, An investigation of model selection criteria for neural network time series forecasting, European Journal of Operational Research 132, pp. 188-102, 2001.

[10] A.Sfetsos, C.Siriopoulos, Combinatorial time series forecasting based on clustering algorithms and neural networks, Neural Compute & Applic,, pp.56-64, 2004.

[11] Liu,Z. F., X. p., Wang, S. W., & Liu, G. F. Recycling strategy and a recyclability assessment model based on an artificial neural network, Journal of materials processing technology, 129, pp500-506, 2002..

[12] Nie, X. H., Huang, G. H., Li, Y. P., &Liu, L.IFRP: A hybrid interval-parameter fuzzy robust programming approach for waste management planning under uncertainty, Journal of environmental management, 84, pp1-11, 2007.

[13] Chi, Y., Wen, J. M., Zhang, D. P., Yan, J.H., Ni, M. J., &Cen, K. F,HCL emission characteristics and BP neural networks prediction in MSW/coal co-fired fluidized beds. Journal of environmental science, 17, pp699-704, 2005.

[14] Shu, H. Y., Lu, H. C., Fan, H. J., Chang, M. c., & Chen, J.C., Prediction fro energy content of Taiwan municipal solid waste using multilayer perception neural networks. Journal of air and waste management association, 56, pp852-858, 2006.

[15] Jalili, M., & Noori, R. Prediction of municipal solid waste generation by use of artificial neural networks: A case study of Mashhad. International journal of environmental research, 2, pp22-33, 2008.

[16] Karaca, F., & Ozkaya, B. NN-LEAP, A neural network based model for controlling leachate Flow rate in a municipal solid waste landfill site. Environmental modeling and software, 21, pp1190-1197, 2006.

[17] Grossman, D., Hudson, J.F., Mark, D.H., Waste generation methods for solid waste collection. J. Environ. Eng. ASCE 6, pp1219– 1230, 1974.

[18] Niessen, W.R., Alsobrook, A.F., Municipal and industrial refuse: composition and rates. In: Proceedings of National Waste Processing Conference, USA, pp112–117, 1972.

[19] Chang, N.B., Pan, Y.C., Huang, S.D., Time series forecasting of solid waste generation, J. Resource. Manag. Technol, 21, pp1–10, 1993.

[20] Chang, N.B., Lin, Y.T., An analysis of recycling impacts on solid waste generation by time series intervention modeling, Resour.Conserv. Recy. 19, pp165–186, 1997.

[21] Katsamaki, A., Willems, S. and Diamadopoulos, E. 'Time series analysis of municipal solid waste generation rates', *Journal of Environmental Engineering*, Vol. 124, pp.178–183, 1998.

[22] Chen, H.W., Chang, N.B., Prediction of solid waste generation via grey fuzzy dynamic modeling, Resour. Conserv, Recy.29, pp1–18, 2000.

[23] Singhmar, A., Agarwal, A., Nema, A.K. and Mittal, A.K., 'Prediction of MSW in Delhi: application of sARIMA Model', Proceedings of 19th International Conferences on Solid Waste Technology and Management, Philadelphia, USA, Available on 2004.http://www2.widener.edu/~sxw0004/19proceedings.html

[24] Srivastava, A.K. and Nema, A.K. 'Comparison of artificial neural network and ARIMA models for forecasting solid waste quantities', *Proceedings of Indian International Conference on Artificial Intelligence (IICAI-05)*, pp.924–937, 2005. http://www.iiconference.org

[25] Guptha, S., Mohan, K., Prasad R.K., Guptha S. and Kansal, A. 'solid waste management in India: options and opportunities', resources, conservation and recycling, Vol. 24, pp. 137-154, 1998

[26] Khan, M.Z.A. and Burney, F.A. 'Forecasting solid waste composition – an important consideration in resource recovery and recycling', *Resources Conservation and Recycling*, Vol. 3, pp.1–17, 1989.

[27] World Bank, What a waste: solid waste management in Asia, The international bank for reconstruction and development, The World Bank Washington DC, USA. 1999.

[28] Buenrostro, O., Bocco, G. and Vence, J. 'Forecasting generation of urban solid waste in developing countries – a case study in Mexico', *Journal Air and Waste Management Association*, Vol.51, pp.86-93., 2001.

[29] Sahin, U., Ucan, O. N., Bayat, C. and Oztorun, N., Modeling of SO_2 distribution in Istanbul using artificial neural networks, Environ. Model, Assess. 10, pp135-142, 2005

[30] McCulloch, W. S. and Pitts, W., A logical calculus of the ideas imminent in nervous activity. Bull.Math, Biophys. 5, pp115-133, 1943.

[31] Minsky, M. L. and Papert, S. A., Perceptrons, MIT Press, Cambridge, MA. 1969.

[32] Rumelhart, D. E. and McClelland, J. L., Parallel Distributed Processing: Explorations in the Microstructures of Cognition, Vol. 1, MIT Press, Cambridge, 1986.

[33] Ashwini Bapat, Dr.Prakash Bapat, Development and Testing of an Efficient Artificial Neural Network Algorithm and Its Effectiveness for Prediction of Insurance Claims International Journal of Innovation, Management and Technology,Vol1,No3,pp 286-291,August 2010.

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