Sustainable Development Practice - Development of Predictive model to forecast the Generation of Municipal Solid Waste in Davangere (Smart City), Karnataka

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Abstract: Municipal Solid Waste (MSW) is an outcome of human activities. In a populated country like INDIA, majority of cities facing problems associated with MSW. Migration of people from rural to urban is adding fuel to this problem. The local governing bodies trying hard to manage municipal solid waste. Many of them started treating these waste as resources and trying to convert them into a renewable energy. The management of MSW has considered as a prime activity with importance for the sustainable development of the city. The main objective of this paper is to identify the major influencing variables that affect the generation of solid waste and to develop a predictive model for better management of MSW. The study was undertaken for Davangere in the state of Karnataka, India which is under the scheme of smart city. The sustainable development of a city needs a sustainable approach towards the Solid Waste Management. The suitable predictive model will certainly help city administrative body to adopt best practices. In this research the linear predictive methods were employed to develop the predictive model. The total solid waste generation, total population, households, per capital income, working age population (15-59 years) and literacy rate were considered as the variables for the study. The Correlation and Principal Component Analysis were executed followed by regressing the dependent variable (total solid waste generation) by using principal components. The regression equation was arrived with the R^2=.9134.

Keywords: Solid waste management, environmental, Karnataka, smart city

Introduction

Development of a Municipal Solid Waste Management (MSWM) plan is a complex process. As a foundation and prerequisite for efficient MSWM plan, quantification and prediction of Solid Waste (SW) generation is very much essentials. Municipal Solid Waste (MSW) prediction cannot be done directly and depends on so many factors. In actual practices, due to uncertainties and unavailability of sufficient data, modelling methods are needed for prediction of MSW generation. There is a need for mathematical model to predict the generation of Municipal Solid Waste (Chakrabarty, 2016). There is a need for developing and adopting a cost efficient model (Beigl P, 2008). One of the most prominent factors which should play a vital role is the role of Community as a stake holder and their inclusion in the entire process of managing the solid waste is going to be crucial (KumarGhatak, 2016).

It is clear that no one single method of MSW disposal can deal with all materials in an environmentally sustainable way. As such, a suitable approach in MSW management should be an integrated approach that could deliver both environmental and economic sustainability. With increasing environmental concerns, the integrated MSW management system has a potential to maximize the useable waste materials as well as produce energy as a by-product (Kaosol T, 2009). The prediction of solid waste is going to be important element to manage the same (Beigl P, 2008).

In India, the collection, transportation and disposal of MSW are unscientific and chaotic. Uncontrolled dumping of wastes on outskirts of towns and cities has created overflowing landfills, which are not only impossible to reclaim because of the haphazard manner of dumping, but also have serious environmental implications in terms of ground water pollution and contribution to global warming. Burning of waste leads to air pollution in terms of increased TSP and PM10 emissions, which is equivalent to vehicular emissions at times. (Shuchi Gupta, 1998).

Since this is a burning issue and there is a need for accurate prediction to manage the solid waste in a better way. The regression analysis and time series analysis can be used as a potential tool to forecast the Municipal Solid Waste. It is also found that Population aged 15–59 years and total MSW strongly influences the results (Ghinea C, 2016).

Municipal Solid Waste situation and management in Davangere (Smart City), Karnataka:

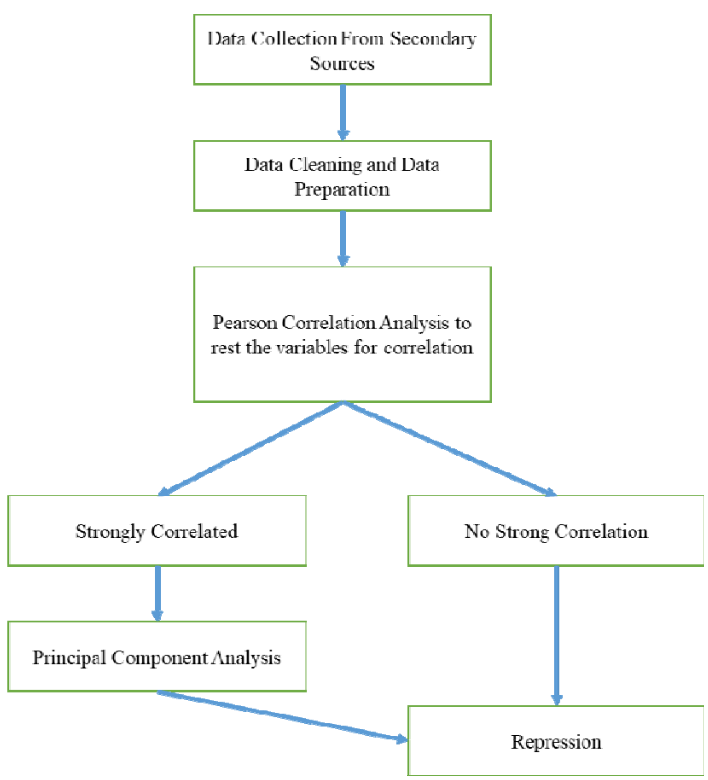
The smart city project guidelines in India is insisting the cities to comply 100% Door to Door collection of solid waste from the households. Components of waste management was much discussed in-terms of collecting the waste from household, commercial establishments etc. The solid waste is considered as a serious concern which impacts the health and sanitation factor of every citizens of city. The Cleanliness of the city depends on the wastage and sanitation. The smart city project guideline insist the cities to adopt better management practices of solid waste and ask them to adopt 100% Door to door collection of the same. The other schemes like Swachh Bharat Mission is also playing a vital role in creating awareness amongst the citizens about their role in management of solid waste.

Seven cities from Karnataka got approval under smart city scheme in India. They are: Belagavi, Bengaluru, Davanagere, Hubli-Dharwad, Mangaluru, Shivamogga, and Tumakuru. Davangere located at the centre part of Karnataka showed remarkable progress in-terms of commercial activity and education. Earlier considered as “Manchester of Karnataka”, now it’s a hub for education, agriculture-oriented mills, hospitals and other business establishments. The Davangere represents a typical tier 2 city which has a potential to grow further. The city is witnessing lot of human activity and will continue to do so. As mentioned in the introduction, the solid waste is an outcome of human activity and there is a need to address this issue. By identifying the relevant variable, collecting appropriate data and adopting a better predictive tool will help to develop a predictive model. The main intention of this research paper lies in that line. Since the city Davangere represents a typical characteristics of smart city, the model can be used for the other smart cities in Karnataka.

The predictive model and the ICT infrastructure on the smart city can join hands to manage the Solid Waste in a better way. This helps the city to grow sustainably and will have minimum impact on the environment.

Data Inputs and Data Interpretation

The following diagram depicts the way the research conducted



The method adopted to develop the predictive model was mainly taken from the research work titled "Development of an Appropriate Model for Forecasting Municipal Solid Waste Generation in Bangkok" (Nayseang Sun, 2017)

Data Collection

The data was collected based on the variables identified which are potentially influence the generation of solid waste in smart cities. These variables are total Municipal Solid Waste, Total population of the city, Population of Working Age Group (Between 15 – 59 Years) and the Per Capita Income of the Households. The description of these variable and their source is mentioned in the table 1.

Data Cleaning and Data Preparation:

The Data was mostly collected from Smart City Open Data Portal, the missing data has been substituted by the method of imputation. The appropriateness of the data was checked by applying logic associated with the data. The necessary data were extracted from Karnataka economic survey report – 2019-20.

Pearson Correlation

The multicollinearity was checked between the variables for all the cities and it has been shown in the table 2. The table indicated that the waste generation is positively correlated with most of the variables considered for the study. The correlation analysis is done for all the variables in all the smart cities of Karnataka.

Principal Component Analysis (PCA)

The principal component analysis is a statistical method, is used to reduce the input variables complexity and avoid the multi-collinearity amongst the variables. This analysis explains the maximum amount of variability with few number of principal components. This process will help to concert the variables into principal components that are linear combination of original variables. In this research 5 variables were considered for the study and 5 principal components were created. These were showed in table 3.

Table 1: Variable considered for the research

Variables	**Description**	**Unit**	**Source of Information**
Total Municipal Solid Waste Generated	The solid waste generated by the human activity in city by the households and other establishments	Tone /Year	Smart City Open Data Portal
Households	Total Number of registered households and other commercial establishments	None	Smart City Open Data Portal
Total Population	Total number of people who are residing in the city	Capita	Smart City Open Data Portal
Per Capital Income	Amount of money earned per person in a city per year	Rupees / Year	KARNATAKA ECONOMIC SURVEY 2019-2020
Working Age Group 15-59 Years	The total population fall between the age group of 15 to 59 years	Capita	Smart City Open Data Portal
Literacy Rate	Number of people who are able to read and write for individuals, communities and societies.	Percentage	Smart City Open Data Portal

Dependent and Independent variable

Dependent Variable	Independent Variable
Total Municipal Solid Waste Generated	Households
	Total Population
	Per Capital Income
	Working Age Group 15-59 Years
	Literacy Rate

Table 2. Pearson Correlation between the variables

	MSW Generated	*Households*	*Population*	*Per Capital Income*	*Working Age Group 15-59 Years*	*Literacy rate*
MSW Generated	1					
Households	0.97458726	1				
Population	0.937792496	0.836185814	1			
Per Capital Income	0.985635625	0.922756118	0.982958211	1		
Working Age Group 15-59 Years	0.945842656	0.849087445	0.999712877	0.987080844	1	
Literacy rate	0.834823456	0.823456743	0.882345677	0.974563212	0.91234538	1

Table 3: Correlation Matrix

Correlation Matrix

		PC1	PC2	PC3	PC4	PC5
Correlation	Number of Households	1.000	.480	-.192	.344	.882
	Total Population	.480	1.000	.566	.222	.370
	Working Age Group 15-59 Years	-.192	.566	1.000	.559	-.409
	Per Capital Income	.344	.222	.559	1.000	-.054
	Literacy Rate	.882	.370	-.409	-.054	1.000

Table 4: Total Variance explained

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	2.257	45.134	45.134	2.257	45.134	45.134	2.210
2	1.900	37.995	83.129	1.900	37.995	83.129	1.966
3	.774	15.476	98.605				
4	.069	1.382	99.986				
5	.001	.014	100.000				

Extraction Method: Principal Component Analysis.

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

Regression Analysis

Technique of establishing one variable based on the values of other variable whenever two variables are correlated is called regression. The response variable which is dependent variable will change according to the predictor variable i.e. independent variable.

Dependent Variable = Intersect + Slope (Coefficient)*Independent Variable

Or Y = a + bX

Where Y = Dependent Variable / Response variable

a = Constant / Intersect

b = Slope / Coefficient

X = Independent Variable

Results and Discussion

Principal Component Analysis – Regression Analysis

The correlation matrix indicates that the first three Principal Components are explaining the 98% of the variability, hence it is clear that these 3 components are representing the variation in the data. The PCA was performed on the data to reduce the size of the problem and to account for correlations among few variables. The first 3 (PC1, PC2, PC3) principal components were taken to regress on the dependent variable i.e. MSW generated. The model has got R^2=.9134, this indicated the 91.34% of variation in the response represents this model.

The following is the regression equation which represents the predictive model for predicting the generation of Municipal Solid Waste.

Y = 81006 + 0.02318PC1 + 0.01894PC2 + 0.008791 PC3

Conclusion

The predictive forecasting model is of vital importance in managing the Municipal Solid Waste and helps to draft the disposal plans. The three principal components were considered to develop the regression equation which will possibly explains the variables such as household, total populat (Daskalopoulos E, 1998)ion, per capital income, working age group (15 – 59 Years) and literacy rate. These variable exist with high co-efficient in principal components PC1, PC2 and PC3.

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