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PREDICTION OF WASTE COLLECTION AMOUNT IN FUTURE BY MEANS OF PYTHON MODELING AND COST ANALYSIS IN DHAKA SOUTH REGION

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ABSTRACT

With accordance to the urbanization, advancement of technology and rapid development of the country the standard of living in Dhaka city is also improving, and the rate of Per Capita Waste Generation (PCWG) has also increased over the years, being population the pivotal point of waste management. The waste in the south region of Dhaka is comprised of different types such as municipal solid waste, electronic waste, hazardous medical waste, food waste, construction waste, and industrial hazardous waste in which municipal solid waste is the majority of the waste. The Total Waste Collection Amount (TWCA) in Fiscal Year (FY) 2019-2020 is 927,100 Ton with a growth rate of 7.7% than previous FY. The TWCA has an increasing trend seen from FY 2015-2016 to FY 2019-2020 which will be continued for the upcoming year with a positive growth rate due to the increase of PCWG. To quantify the approximate TWCA (a function of year) for the incoming years a Linear Regression (LR) method is introduced in collaboration with Python Modeling (PM) by using of present available data. LR method by way of PM is also useful to estimate the operation-wise Solid Waste Management (SWM) expense in future by predicting TWC. The SWM operation in Dhaka South City Corporation (DSCC) is categorized into four types: i) Cleaning of roads and drains, ii) Collection and transport, iii) Landfill operation, and iv) Repair works. The total expenditure for SWM in FY 2019-2020 is found 2684.68 Million BDT.

Key words: Total Waste Collection Amount, Linear Regression, Python Modeling, Solid Waste Management

INTRODUCTION

Solid waste management is a critical concern for urban areas worldwide, particularly in rapidly developing regions, where population growth and urbanization outpace infrastructure development (Dyson & Chang, 2005). It becomes a very challenging task for Bangladesh also because the is one of the most densely populated country in the world. Specially in Dhaka a massive population density is observed. Dhaka generates over 6,500 tons of waste daily, and this figure is expected to escalate significantly in the coming decades (Ahsan et al., 2014). And the waste generation rate is increasing abruptly due to the high population density. Efficient prediction of waste generation using advanced data-driven methods can significantly enhance planning and operational efficiency in waste management systems (Guo et al., 2021). Which is highly applicable for Dhaka city. The use of Machine Learning (ML) algorithms in municipal waste management has shown great promise in improving prediction accuracy and optimizing resources" (Wu et al., 2020). ML like Python Modeling is very suitable to predict the future waste collection amount with very high accuracy rather than manual calculation. In this study the recent trend of waste generation is observed at first. Then ML is used to predict the waste generation. After predicting that, cost analysis or cash flow analysis has been needed which is also very crucial for this study. Cost analysis in solid waste management systems is essential to identify economic inefficiencies and allocate resources effectively" (Sankoh et al., 2012). Community-based waste management practices in Bangladesh have demonstrated the potential for localized solutions to address waste challenges" (Enayetullah & Sinha, 2011). Urban waste collection systems often face challenges such as irregular collection schedules, inefficiencies in routing, and inadequate resource allocation" (Inghels & Dullaert, 2011). Dhaka South City Corporation has been striving to improve its waste management systems but continues to face challenges due to

rapid urban expansion and resource constraints" (Mahmud, 2018). By integrating predictive modeling with cost analysis, urban planners can develop more sustainable and efficient waste management practices" (Runsewe et al., 2020). Accurate prediction of waste generation is vital for achieving sustainable urban development and mitigating the environmental impacts of solid waste" (United Nations Environment Programme, 2010)

METHODOLOGY

Selection of Study Area

Being Dhaka the capital of Bangladesh is one of the most densely populated areas in the world. A significant amount of waste is generated due to this high density of population. It's a great challenge to manage these waste as well as to recycle these for reducing the surrounding environmental impact. Rapid urbanization and subsequent developments are seen in the south region of Dhaka (having an area of 109 sq. km with a population of 6.3 million) which can be treated as a threat. There are a Total Number of Zone 10 and Total Number of Ward 75 in where The Average Population density of this area is 57,798 per sq. km. Generation of waste at massive amounts and their improper collection and recycle process led to the selection of this area. Lack of the proper management of all kinds of waste is responsible for environmental hazard and health risk in this location. Waste collection is the preliminary step for waste management. For this reason predicting the TWCA for the incoming year is crucial for waste management.

Data Collection and Analytical Modeling Approach

All the data relevant to this study are collected from the Waste Management Report 2019-2020, Waste Management Department (WMD) of Dhaka South City Corporation (DSCC). This report is available in online platform. The goal of this study is to build a model that will predict the TWCA by using the collected data. For this work a Python based model is set up which will apply Linear Regression (LR) for the prediction. Linear Regression is used because a linear increasing tendency is observed in the Yearly Waste Collection Amount for the consecutive five years. And after that this model will predict the TWCA for any future year being it is a function of time. But the accuracy depends on the future trend of Total Waste Generation (TWG). If TWG's increasing rate remains approximately the same than the prediction model will predict with a very high accuracy. Also the accuracy will be reduced for the year that is more faraway from the observed year.

Python Modeling

It is used for automatic accurate prediction and can be performed in any IDE for Python

```
import numpy as np
import matplotlib.pyplot as plt
from scipy import stats
# Dataset (x, y)
x = np.array([2016, 2017, 2018, 2019, 2020])
y = np.array([687466, 768030, 784750, 860305, 927100])
# Linear Regression model using scipy stats
slope, intercept, r_value, p_value, std_err = stats.linregress(x, y)
# Function to predict y for new x values (outside the given range)
def predict_linear(x_new):
    return slope * x_new + intercept
# Predict y for new x values (example: outside the range of 2 to 30)new_x_values =
np.array([1, 35])
 # Example: x values outside the range of 2 to 30
# Predictions using linear regression
linear_predictions = predict_linear(new_x_values)
# Output predictions for new x values
for x_new, y_pred in zip(new_x_values, linear_predictions):
    print(f"For x = {x_new}:")
    print(f"  Linear Regression Prediction: y = {y_pred:.2f}")
    print()
# Plot the original data and the linear regression line
x_range = np.linspace(min(x) - 5, max(x) + 5, 100)  # Extend x-range for better visualization
y_linear_fit = predict_linear(x_range)
# Plot original data and the fitted linear regression line
plt.scatter(x, y, color='blue', label='Original Data')
plt.plot(x_range, y_linear_fit, color='red', label=f'Predicting Equation: y = {slope:.2f}x +
{intercept:.2f}')
plt.xlabel('Year')
plt.ylabel('TWCA (Ton/year)')
plt.legend()
plt.title('Linear Regression Fit')
plt.grid(True)
```

```
plt.show()
```

RESULTS AND DISCUSSION

PCWG scenario in 2019-2020

Due to the increased number of infrastructure developments, shopping complexes, restaurants, markets, bazaars along with roadside tea-stalls, floating vendors, and flower markets on the footpath the amount of waste in Dhaka South City Corporation (DSCC) is increasing day by day. In 2019-2020, per capita per day waste generation is found 0.72Kg which was previously 0.65Kg and 0.575Kg in 2018-2019 and 2017-2018 respectively. PCWG varies from ward to ward due to the economic status and lifestyle pattern. People in Ward-37 and Ward-20 have been generating much more waste compared to other wards and per capita per day waste is 3.6Kg and 2.3Kg respectively. These wards cover places like Sadarghat and Topkhana road where a lot of floating markets, restaurants and commercial spaces can be found. Whereas only 0.26 kg and 0.32 kg per capita waste is being generated from Ward-24 and Ward-2. The highest and lowest top 5 per capita waste generating wards are depicted in the following bar charts:

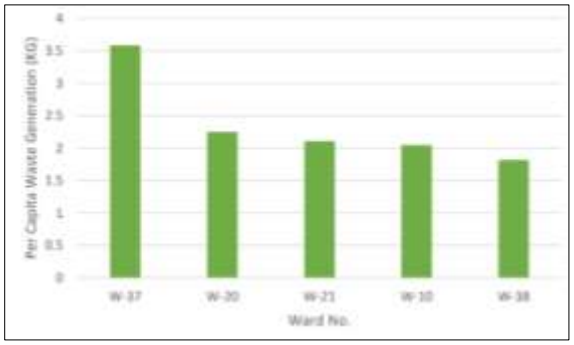

Figure 1 Highest per capita waste generating 5 wards.

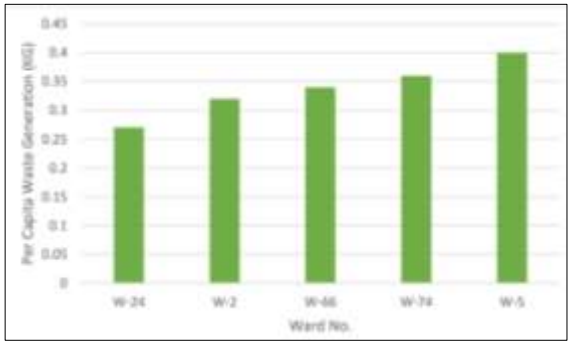

Figure 2 Lowest per capita waste generating 5 wards.

Waste Collection Scenario in 2019-2020

Though DSCC collects municipal solid waste that citizens generate every day but is seen that citizens often discharge waste into open spaces, drains, canals, or their own backyard rather than to dump in DSCC's designated secondary collection points. The highest and the lowest amount of waste is collected from Ward-15 and Ward-3 respectively in FY 2019-2020. The highest and lowest top 5 ward-wise amounts of waste collected in FY 2019-2020 are presented in the subsequent chart.

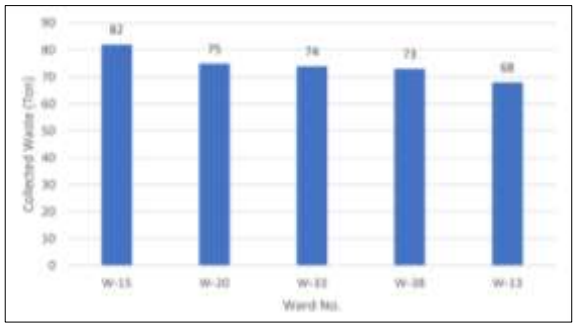

Figure 3 Highest amount of waste collecting 5 wards.

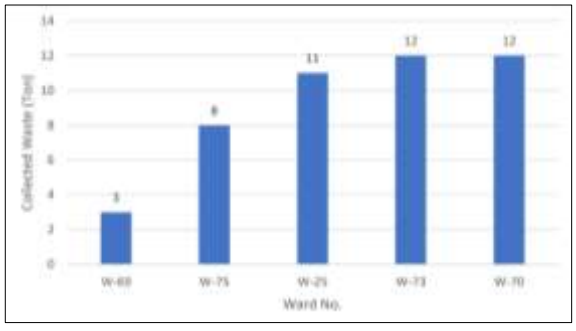

Figure 4 Lowest amount of waste collecting 5 wards.

Waste Collection Trend

DSCC currently collects 78% of solid waste by using their available vehicles. 90% collection rate could be achieved by introducing more vehicles and adopting more efficient and modernized collection system in the city. The waste collection growth rate since FY 2015-2016 is shown in table and graph below. The solid waste sources and their final disposal scenario is depicted in the waste flow diagram for the FY 2019-2020 as shown below.

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Table 1: Yearly Waste Collection Amount and Growth Rate

Year	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020
Total Waste Collection (Ton/year)	687,466	768,030	784,750	860,305	927,100
Monthly Average Collection (Ton/month)	57,289	64,002	66,650	73,067	78,740
Daily Average Collection (Ton/day)	1,883	2,104	2,150	2,357	2,540
Waste Collection Growth	-	12%	4%	9.6%	7.7%

Prediction of TWCA

In table 1 TWCA are given for the consecutive five years. With accordance to it necessary steps for Waste Management were taken. Here TWCA plays a great role being the primary steps of Waste Management. A good amount of costs are expended for the waste collection. So to predict the TWCA for the future is crucial. After running the Python model a linear relationship has been established in between TWCA and Year (last year of FY). This relation will help to determine the prediction. From the output console of Python model a linear equation is established.

TWCA predicting equation: TWCA(Ton/year) = 57154.30 x year – 114531847.20 (1)

The TWCA can be quantified by inputting year (after 2020). And accuracy is high for the nearer year like 2028. And the model will lose its accuracy when a year of faraway is taken like 2050 due to its characteristics to maintain a specific uniform increasing gradient for either short-term or long-term period.

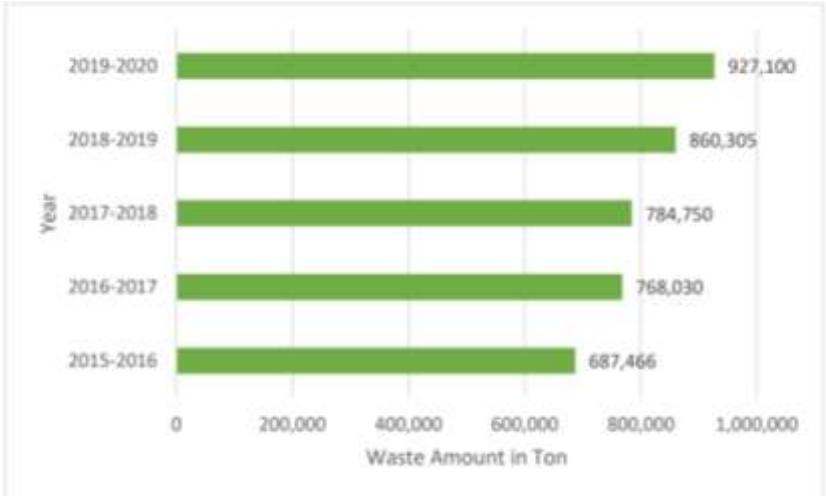

Figure 5: Waste collection trend (year wise)

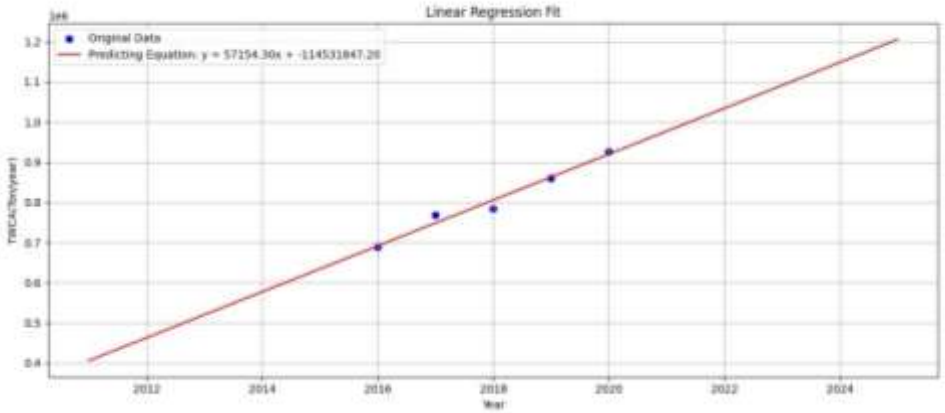

Figure 6 Prediction output from Python modeling

Table 2 Predicted TWCA for some years

Year	Total Waste Collection (Ton/year)
2024-2025	1205610
2027-2028	1377073
2029-2030	1491382
2034-2035	1777153

Expenditures Related to SWM

The total SWM expenditures have increased since FY 2012–2013 and reached approximately 4.65 billion BDT in FY 2016–2017, of which 86% and 14% were revenue and development expenditures, respectively. In FY 2016–2017, more than 5.0 billion BDT of the budget was allocated for land acquisition and development of the Matuail LFS expansion in accordance with the approved Development Project Proposal (DPP). The SWM operation in DSCC is categorized into four types: i) Cleaning of roads and drains, ii) Collection and transport, iii) Landfill operation, and iv) Repair works. The operation-wise expenditures of SWM are shown in the chart below.

Table 3 Operation-wise SWM expense in 2019-20 FY

Operation	Yearly Expenditure (MBDT)	Percentage
Cleaning of roads and drains	397.38	14.80
Collection and transport	1,966.80	73.26
Landfill operation	251.50	9.37
Repair works	69.00	2.57
Total*	2684.68	100

CONCLUSION

In the current situation, waste generation has become a point of concern throughout the world. And the rapid increase of waste is alarming. Bangladesh isn't out of this phenomenon. Moreover a huge amount of waste is generated every day in Bangladesh especially in Dhaka South region but most of these aren't recycled or treated properly. The per capita waste generation in Dhaka south region is 0.72Kg. And the total waste collection amount by DSCC was 927,100 Ton in 2019-2020 FY. Also the predicted waste collection amount is found 1777153 Ton in 2035. Also a vast amount of cost is expended for waste management. In 2019-2020 FY 2684.68 MBDT was expended for solid waste management. So the prediction of TWCA is very advantageous for waste management. This prediction will also help to give a preliminary idea of cash flow for expenditure. The prediction may not be exactly the same but approximately would be close enough because Python modeling has been applied here for sufficient accuracy. Some administrative measure relevant to waste management would be taken in advance if the TWCA is known by prediction. Actually waste management is a huge and long term task where cost analysis plays a vital role. Cash flow analysis in each individual sector will help to identify the importance of these sectors. To keep the environment safe and sound waste management plays a vital role.

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