



GUJARAT TECHNOLOGICAL UNIVERSITY

(Established by Government of Gujarat under Gujarat Act No. : 20 of 2007)

ગુજરાત ટેકનોલોજીકલ યુનિવર્સિટી

(ગુજરાત સરકારના ગુજરાત અધિનિયમ ક્રમાંક : ૨૦/૨૦૦૭ દ્વારા સ્થાપિત)

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Abstract of the Thesis



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Faculty: Engineering

Discipline/Branch: Civil Engineering

Title of the Thesis: A comprehensive framework for municipal solid waste forecasting & route optimization: A comparative analysis of different machine learning models for the city of Surat

Abstract

Indian cities are urbanising faster than their municipal solid waste (MSW) systems can adapt, with collection infrastructure, forecasting practice, and routing formulations often assuming levels of data availability and GPS accuracy that most Urban Local Bodies (ULBs) do not possess. This thesis develops an integrated three-part framework—forecasting, route optimisation, and decision support—built and tested on data from the Surat Municipal Corporation (SMC), Gujarat, to address these deficiencies within a single empirically grounded programme of research.

The forecasting component constructs a 419-feature engineering pipeline from 186 months of SMC waste generation records (June 2009–December 2024) and comparatively evaluates seventeen models spanning linear and regularised regression, kernel methods, ensemble learning, deep learning architectures, and classical time series approaches under an eight metric evaluation protocol. Across this uniform tabular setting, Ordinary Least Squares regression achieves the strongest overall performance ($R = 0.9972$, $MAPE = 1.43$), outperforming all tested deep learning architectures, including LSTM, and demonstrating that systematic feature engineering can supersede architectural complexity in data-scarce municipal forecasting contexts. A separate interrupted time series analysis on an independent 196-month raw dataset isolates the structural impact of the COVID-19 disruption, with linear models incorporating a pandemic indicator achieving up to a 16% reduction in RMSE relative to non-indicator baselines.

The route optimisation component unfolds in three stages. The first stage, published in the International Journal of Applied Mathematics (2025), couples an LSTM forecaster with a capacitated vehicle routing (CVRP) solver on a synthetic network scaled to Surat and demonstrates substantial reductions in collection distance and fleet size as a proof of concept. The second stage routes forecasted demand through eight GPS verified transfer stations and the Khajod disposal site, quantifying an 82% theoretical efficiency potential relative to current operations and highlighting transfer stations as operational bottlenecks rather than passive depots. The third stage analyses 662,803 real operational collection records from October 2025, revealing that only 8.6% of unique collection point names can be geocoded to coordinates and motivating IMPACT, a five component



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GPS-free framework validated on the full operational dataset. Using an XGBoost classifier with SHAP attribution, IMPACT demonstrates that contractor noncompliance, rather than fleet capacity, is the dominant cause of missed collection stops across all nine zones.

The decision support component operationalises the forecasting and optimisation outputs within a four-layer architecture—Data Ingestion, Model Execution, Analytics, and User Interface—implemented as a Streamlit proof of concept with verified stakeholder dashboards and data sources. The system is explicitly designed to be GPS-free and IoT-free, integrating monthly forecasting and near-real-time optimisation outputs via a demand scalar and role-specific interfaces for SMC personnel, and is structured for replication in Indian ULBs that lack GPS tracked fleets or dense GIS infrastructure. The framework is aligned with the Smart Cities Mission, Swachh Bharat Mission 2.0, and Sustainable Development Goals 11, 12, and 13, and delivers eighteen original methodological, empirical, and practical contributions mapped to three formally approved research objectives and five major literature gaps across forecasting, feature engineering, routing, GIS, and integrated decision support.

Collectively, the research provides a compliance first governance recommendation for a tier-II Indian municipality, validated on large-scale operational data, and demonstrates that integrated, GPS-free, machine learning driven forecasting and routing, supported by a deployable decision support system, can substantially improve the reliability, efficiency, and policy alignment of MSW collection systems in Surat and comparable Indian and developing economy urban contexts.

This PhD Thesis will help in

- Improving municipal solid waste forecasting and planning in Indian ULBs.
- Supporting GPS-free route optimisation and operational efficiency assessment.
- Developing decision support for compliance-first Smart City waste governance.
- Enabling replication of integrated forecasting, optimisation, and DSS frameworks in comparable urban contexts.

List of Publication(s):

- 1) Rathod, A. R., & Patel, V. M. (2025). A systematic review of models for predicting municipal solid waste generation for efficient waste management. International Journal of Scientific Development and Research.
- 2) Rathod, A. R., & Patel, V. M. (2025, May 3). Comparative study of machine learning techniques for predictive modeling: Approaches, applications, and performance evaluation. In 27th ISTE Conference on "Revolutionizing Multidisciplinary Technical Education with Innovative Instructional Strategies: Vision 2047 for New Bharat" (pp. 312-316).
- 3) Rathod, A. R., & Patel, V. M. (2025). AI-driven decision support system for optimized municipal solid waste management: A machine learning and route optimization framework for smart cities. International Journal of Applied Mathematics. <https://doi.org/10.12732/ijam.v38i12s.1565>
- 4) Rathod, A. R., & Patel, V. M. (2026). Data-driven automation for solid waste forecasting using machine learning, with COVID-19 impact analysis: A case study of Surat, Gujarat. Journal of Solid Waste Technology and Management. <https://doi.org/10.5276/jswtm/iswmaw/522/2026.515>
- 5) Rathod, A. R., & Patel, V. M. (2026). A comparative study of advanced machine learning and deep learning models for municipal solid waste forecasting: A case study of Surat, India. Journal of Engineering and Technological Sciences, 58(5), 613–629. <https://doi.org/10.5614/j.eng.technol.sci.2026.58.5.1>

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Ph.D. Programme

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