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An Ensemble Learning-Based Analytical Framework for Forecasting Workforce Efficiency in GHMC Operations

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ABSTRACT

Efficient workforce management remains a persistent challenge for large urban local bodies in India. The Greater Hyderabad Municipal Corporation (GHMC) oversees a complex network of civic services that demand consistent employee productivity across diverse functional departments. Existing evaluation systems are predominantly retrospective and fail to leverage the predictive power of modern artificial intelligence. This thesis presents a comprehensive analytical modelling approach that forecasts the efficiency of GHMC employees through carefully designed AI ensemble algorithms.

A structured research methodology is adopted, beginning with the identification of key performance indicators relevant to municipal work, including quantitative measures (task throughput, response time, attendance regularity) and qualitative indicators (citizen satisfaction indices, supervisory ratings). Data are gathered from GHMC's internal management information systems, cleaned for missing values and outliers, and transformed into a unified feature space. Class imbalance and departmental heterogeneity are addressed through stratified sampling and domain-specific feature scaling.

The core of the study lies in the design, implementation, and comparative evaluation of ensemble learning architectures. Bagging, boosting, and hybrid stacking techniques are systematically explored, with particular emphasis on algorithms known for handling tabular administrative data—Random Forest, LightGBM, CatBoost, and multi-level stacking ensembles. Each model is subjected to rigorous hyperparameter tuning using grid and Bayesian optimization strategies. Performance is benchmarked on held-out test sets and further validated through temporal cross-validation to ensure generalizability across different operational cycles.

Interpretability is enhanced through SHAP (SHapley Additive exPlanations) analysis, which identifies the most decisive drivers of predicted efficiency and provides transparent explanations suitable for administrative stakeholders. Experimental outcomes indicate that the optimized ensemble models deliver superior predictive accuracy and stability compared with individual learners, while maintaining computational feasibility for periodic institutional use.

The resulting framework is packaged as a practical decision-support system that can generate efficiency forecasts, highlight high-risk underperformance zones, and recommend resource reallocation strategies. The research advances the application of ensemble AI in public-sector human resource analytics, offering a scalable, data-driven alternative to conventional appraisal methods. Findings are expected to assist GHMC leadership in evidence-based workforce planning and may serve as a reference model for other municipal corporations seeking to modernize employee performance prediction.

Keywords: *AI Ensemble Algorithms, Workforce Analytics, Municipal Administration.*