

Forecasting Unplanned Repair Demand in Military Helicopter Engine Components: A Decision Support System Design Using Time Series and Machine Learning Approaches

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Abstract

This study addresses the challenge of forecasting unplanned repair demand for military helicopter engine components, which is responsible for depot-level maintenance of Turkish Land Aviation aircraft. Current demand forecasting relies heavily on expert intuition and simple historical averages, creating a person-dependent planning process that cannot quantify forecast errors. Using Ishikawa cause-and-effect analysis, the root causes of uncertainty were identified across six categories; Pareto analysis revealed that Material & Supply and Forecasting Method deficiencies account for approximately 50% of the problem burden. To address these, a Decision Support System (DSS) was developed, incorporating an automated data cleaning pipeline, KPI computation, and ten forecasting models: Seasonal ARIMA, Exponential Smoothing, Random Forest, XGBoost, LightGBM, CatBoost, Prophet, Croston, SBA, TSB. Walk-forward validation shows that gradient boosting models (especially LightGBM) achieve the lowest MAE (≈ 15.5), reducing forecast error by 24.3% compared to the existing operational benchmark (Seasonal ARIMA) used at the depot. Lagged demand features proved most influential via permutation importance. The DSS is deployed as an interactive dashboard, standardizing the planning process and enabling proactive procurement decisions.

Keywords

Military Helicopter Maintenance, Unplanned Repair Demand Forecasting, Decision Support System, Time Series, Machine Learning.

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Biographies

Irem Coban is an Industrial Engineering student at Gazi University, Ankara, Turkey. She is expected to graduate in 2027. Her current research focuses on applying machine learning techniques to forecast unplanned helicopter engine repair demands, conducted as her senior capstone project at the 5th Main Maintenance Factory Directorate, which is responsible for depot-level maintenance of Turkish military rotorcraft. She has completed a mandatory production and supply chain internship at Viessmann and gained hands-on experience with multiple ERP systems, including 1C, Canias, Nebim, and Oracle. Her technical competencies include Python, SQL, VBA, and statistical software such as SPSS, Minitab, and Arena. She is also proficient in PLC programming and robotics, having founded her own robotics team and achieved national and international awards in robotics competitions. İrem Coban has held leadership roles in several student organizations. She serves as a board member of the Business Society. She has also worked as a

part-time sales consultant, developing customer-facing and operational skills. Her interests lie at the intersection of industrial engineering, machine learning, and product management. She is fluent in Turkish and proficient in English.

Zeynep Aydemir is an Industrial Engineering student at Gazi University, Ankara, Turkey, expected to graduate in 2026. She is the Vice President of the Gazi Business Society, where she has developed skills in corporate communication, project management, and partnership development. She has also served as the President of the Sponsorship Committee of the same society. Her industry experience includes an internship in the Analytics & Innovation Team at Toyota Otomotiv Sanayi Türkiye A.Ş., a production internship at Kaya-Pen, and project work at Eker Plastik, Elimko and Nurol Teknoloji. She has also completed the Women in STEM Education Program organized by Enerjisa Üretim. Zeynep possesses strong technical skills, including advanced proficiency in Microsoft Office, Power BI, Power Automate, Power Apps, Canva, AutoCAD, C#, Python, MSSQL, and Arena. Her academic and project work focuses on production systems, lean manufacturing, digital transformation, database systems, and data analytics. She is fluent in English (advanced level) and has beginner knowledge of Italian. Beyond engineering, she holds a black belt in taekwondo and enjoys body-challenging sports, swimming, hiking, zero-waste living, healthy cooking, drawing, and oil painting. Zeynep aims to combine her industrial engineering knowledge with data analytics and software development to create value-driven solutions in production and defense industry settings.