بسم الله الرحمن الرحيم

﴿ وَقُل رَّبِّ زِدْنِي عِلْمًا ﴾

(سورة طه، الآية 114)

"And say, 'My Lord, increase me in knowledge.'"
(Surah Taha, 20:114)

﴿ صُنْعَ اللَّهِ الَّذِي أَتْقَنَ كُلَّ شَيْءٍ ﴾

(سورة النمل، الآية 88)

"[It is] the work of Allah, who perfected all things."
(Surah An-Naml, 27:88)

﴿ وَمَا بِكُم مِّن نِّعْمَةٍ فَمِنَ اللَّهِ ﴾

(سورة النحل، الآية 53)

"And whatever you have of favor – it is from Allah."
(Surah An-Nahl, 16:53)

إهداء

بسم الله الرحمن الرحيم

﴿ وَقُل رَّبِّ ارْحَمْهُمَا كَمَا رَبَّيَانِي صَغِيرًا ﴾
(الإسراء: 24)
صدق الله العظيم

إلى من غاب عني جسداً، وبقيت حباً في قلبي ما حييت،
إلى والدي الحبيب (رحمه الله)، الذي زرع فيّ العلم،
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Abstract

This research presents a comprehensive reliability and failure analysis of critical equipment in a cement manufacturing plant, aiming to identify dominant failure modes, their root causes, and their effects on operational performance. Based on the methodological framework established in Chapter 3 and the analytical results detailed in Chapter 4, the study employs advanced techniques including Pareto Analysis, Root Cause Analysis (RCA), Failure Mode and Effects Analysis (FMEA), Fault Tree Analysis (FTA), Reliability Metrics (MTBF, MTTR, and Availability), and Weibull Reliability Modeling.

Maintenance data covering the period 2017–2025 were analyzed using AI-assisted tools such as Google Colab and IPython. The findings indicate that mechanical failures dominate across key systems namely the Limestone Crusher, Vertical Raw Mill, Rotary Kiln, and Cement Mills representing the majority of plant downtime and maintenance effort. Pareto analysis confirmed that a limited number of failure categories, such as liner wear, bolt fatigue, and hydraulic leaks, account for over 60% of recorded failures. RCA and FTA revealed that poor design, misalignment, and lubrication deficiencies are recurring root causes.

Reliability metrics showed below-benchmark performance (e.g., LS Crusher Availability = 88.86%), highlighting the need for a transition from reactive to predictive maintenance. The results form a quantitative foundation for implementing a risk-based maintenance (RBM) framework that enhances MTBF, reduces MTTR, and improves system availability through data-driven monitoring and training.

Finally, predictive models in Chapter 5 extend the analysis toward forecasting the most probable failure modes for 2025–2028, supporting proactive maintenance scheduling and optimized reliability management across critical plant systems.

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Abbreviations

- **Aa** : Achieved Availability
- **Ai** : Inherent Availability
- **Ao** : Operational Availability
- **β** : Shape Parameter (Weibull Analysis)
- **CBM** : Condition-Based Monitoring
- **CDP** : Ceramic Disc Plate
- **CDF** : Cumulative Distribution Function
- **CMMS** : Computerized Maintenance Management System
- **FMEA** : Failure Mode and Effects Analysis
- **FTA** : Fault Tree Analysis
- **Hardox** : Wear-Resistant Steel (trademarked)
- **HE** : Heat Exchanger
- **MTBF** : Mean Time Between Failures
- **MTTR** : Mean Time To Repair
- **PDF** : Probability Density Function
- **RCA** : Root Cause Analysis
- **RCM** : Reliability-Centered Maintenance
- **ROI** : Return on Investment
- **RPN** : Risk Priority Number
- **SOP** : Standard Operating Procedure
- **TPM** : Total Productive Maintenance
- **η** : Scale Parameter (Weibull Analysis)