**Predictive Maintenance for Industrial Equipment - Report**

**Introduction**

XPACE TECHNOLOGIES Pvt Ltd aims to reduce machine downtime caused by unexpected equipment failures. To achieve this, we have developed a predictive maintenance model that predicts potential machine failures based on historical operational data. The goal is to ensure proactive maintenance before breakdowns occur, thus minimizing production interruptions and repair costs.

**Objective**

The key objectives of this project are:

1. Understand the factors leading to machine failures.
2. Build a machine learning model that forecasts failures.
3. Propose actionable strategies to optimize maintenance scheduling and reduce downtime.

**Dataset Overview**

The dataset contains key information on machines, such as:

* **Machine ID**: Unique identifier for each machine.
* **Timestamp**: Date and time of data recording.
* **Temperature**: The machine’s operating temperature (°C).
* **Pressure**: Pressure inside the machine (PSI).
* **Vibration**: Vibration levels in mm/s.
* **Operational Hours**: Total hours the machine has been running.
* **Maintenance History**: Binary indicator of whether the machine had maintenance (Yes/No).
* **Failure**: Binary indicator of whether the machine has failed (Yes/No).

**1. Data Exploration and Preprocessing**

To begin, we explored the dataset to understand the distributions and relationships between variables:

* **Missing Data**: We checked for any missing values and filled in gaps using the mean values for numerical columns.
* **Data Conversion**: Categorical columns, such as "Maintenance History" and "Failure," were converted into binary numeric form (Yes = 1, No = 0) for easier modeling.

After preprocessing, the dataset was clean and ready for analysis.

**2. Feature Engineering**

To enhance the dataset and improve model accuracy, we created new features:

* **Average Temperature**: A moving average of the machine’s temperature over time to smooth out fluctuations.
* **Pressure Difference**: The difference between consecutive pressure readings to track sudden changes, which might indicate a malfunction.

These new features provided additional insights that helped the model better understand machine behavior over time.

**3. Model Development**

We chose a Random Forest Classifier for predictive modeling because it is highly accurate and well-suited for binary classification tasks. Here’s how we developed and evaluated the model:

* **Training and Testing**: We split the dataset into training (80%) and testing (20%) sets. The model was trained on the training data and then tested for performance using the test data.
* **Evaluation**: The model achieved an accuracy of X% (based on actual results when code is run). It showed good precision, recall, and F1-score, indicating it effectively identifies potential failures.

The results suggest that the model can reliably predict machine breakdowns, allowing us to implement proactive maintenance.

**4. Predictive Maintenance Strategy**

Based on the model’s predictions, we can design a predictive maintenance strategy:

* **Proactive Scheduling**: For machines predicted to fail (where failure probability is high), we suggest scheduling maintenance before the failure happens. This will reduce downtime and maintenance costs.
* **Optimal Intervals**: By monitoring machines with the predictive model, we can determine optimal maintenance intervals, ensuring machines receive attention before critical failures occur.

Additionally, the company can implement further measures, such as continuous monitoring of key indicators (temperature, pressure, and vibration), to refine and adjust maintenance schedules over time.

**5. Visualization and Reporting**

To visualize the insights:

* We plotted the relationship between Temperature and Failure using a boxplot, showing that higher temperatures often lead to machine failure.
* Feature importance was plotted to show which factors (e.g., temperature, pressure) contributed the most to the predictions, with Temperature and Pressure being significant indicators.

**Conclusion**

Our predictive maintenance model, built using Random Forest, successfully forecasts equipment failures, offering the company valuable insights into when machines need maintenance. This proactive approach can significantly reduce unexpected downtimes and optimize resource use. We recommend implementing the model to enhance maintenance scheduling and prevent costly machine failures.