Industrial Machine Downtime Analytics & Monitoring with Snowflake & Power BI

1. Problem Statement:

In a high-precision manufacturing environment, unplanned machine downtime directly impacts production schedules, delivery commitments, and operational costs. The organization currently collects daily operational and sensor data from multiple machines but lacks a centralized, analytical system to **monitor downtime trends, identify high-risk machines, and understand the key factors contributing to failures**.

The goal of this project is to build an **end-to-end analytics solution** using **Snowflake and Power BI** that enables stakeholders to:

- **Monitor machine downtime in near real time**
- **Identify machines and shop floors with high failure rates**
- **Analyse sensor behaviour associated with downtime**
- **Support proactive maintenance planning**

2. Project Overview:

This project implements a **modern BI architecture** where:

- Raw machine operational data is stored and queried in **Snowflake**
- Analytical modelling, KPIs, and summaries are created in **Power BI**
- Dashboards provide actionable insights for operations and maintenance teams

3. Tools & Technologies:

- **Data Warehouse:** Snowflake
- **Visualization & Analytics:** SQL & Power BI
- **Data Source:** CSV machine operational dataset
- **Modelling Approach:** Raw fact table + KPI & summary tables (Power BI)

4. Dataset Description:

The readings represent continuous operational data collected from machines on each shop floor. These readings capture key parameters such as pressure, temperature, torque, and speed, providing insights into machine performance and health. The company has stored the machine operating data in a single table. Each row in the table corresponds to a single machine's operational reading on a given day.

The data has undergone transformations to enhance analysis, including renaming columns, casting data types, and mapping target class values.

Feature	Description	Unit	Significance
Date	Date of the reading	datetime64	Enables temporal analysis of maintenance history
Machine_ID	Unique machine identifier	category	Enables comparative analysis by machine
Assembly_Line_No	Unique assembly line identifier	category	Enables comparative analysis by assembly line
Hydraulic_Pressure	Hydraulic system pressure	bar	Assesses the health of the fluid power system
Coolant_Pressure	Coolant system pressure	bar	Assesses the health of the coolant system
Air_System_Pressure	Air system pressure	bar	Evaluates the status of air compression
Coolant_Temperature	Coolant system temperature	Celsius	Assesses the health of the coolant system
Hydraulic_Oil_Temperature	Hydraulic oil temperature	Celsius	Assesses the health of the hydraulic system
Spindle_Bearing_Temperature	Spindle bearing temperature	Celsius	Assesses the health of the spindle system
Spindle_Vibration	Spindle vibration level	Micrometers	Evaluates spindle performance
Tool_Vibration	Tool vibration level	Micrometers	Evaluates tool performance
Spindle_Speed	Spindle rotational speed	RPM (Revolutions Per Minute)	Evaluates spindle performance
Voltage	System voltage	Volts	Evaluates electrical performance
Torque	Torque	Newton-meters (Nm)	Evaluates mechanical performance
Cutting	Cutting force	Kilonewtons (kN)	Evaluates cutting performance
Downtime	Operational status	Boolean	Distinguishes whether machines are operating normally or experiencing failures

5. Key Business Questions (Business KPI)

1) Overall Downtime Rate Analysis

1. What is the **overall machine downtime percentage**?
2. Is downtime **increasing or decreasing over time**?
3. Which **machine has the highest downtime**?

2) Predicting Machine Failures & Root Cause

4. Which **shop floor / assembly line** is the most problematic?
5. Which **sensor readings** are most strongly linked to downtime?
6. How do sensor values differ **during downtime vs normal operation**?

3) Time & Trend Analysis

7. Are there specific **days or periods** when downtime is higher?
8. Do rolling trends show **recurring failure patterns**?
9. Which machines should be **prioritized for maintenance**?
10. Are there **early warning indicators** that signal failure risk?