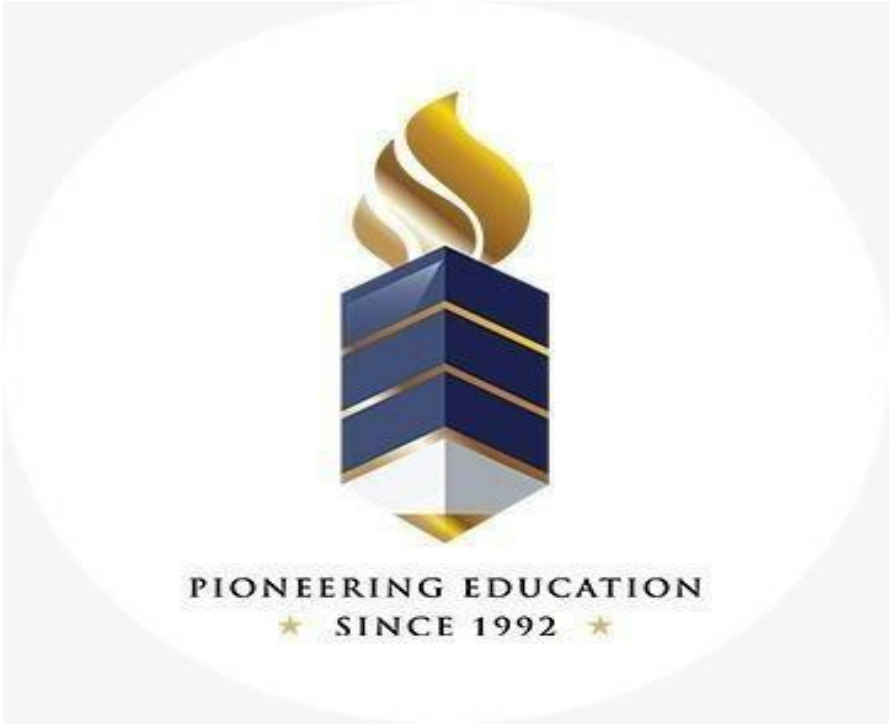
CNCMate: AI-powered CNC analytics platform

Project Synopsis

By

Abhishek Kumar Gupta

Bachelor of Science (Data Science)



DEPARTMENT OF DATA SCIENCE

SHREE L. R. TIWARI DEGREE COLLEGE OF ARTS, COMMERCE & SCIENCE

(***Affiliated to University of Mumbai***)

THANE, 401107

MAHARASHTRA

2025-26

1. Introduction

CNC (Computer Numerical Control) machines form the backbone of modern manufacturing, especially among India's 63 million MSMEs (Micro, Small, and Medium Enterprises). Despite their widespread adoption, most CNC workshops still struggle with:

- Lack of real-time visibility into machine operations
- High unplanned downtimes and sudden breakdowns
- Manual, error-prone logging of jobs and maintenance
- Limited defect tracking and quality control
- No systematic data-driven decision-making

To address these pain points, CNCMate is proposed as a smart, affordable, and modular AI-powered CNC analytics platform. It combines IoT, data engineering, machine learning, and AI to provide MSMEs with real-time monitoring, predictive insights, and business intelligence.

---

2. Project Objectives

- Reduce machine downtime through predictive and prescriptive maintenance
- Improve quality control with AI-powered defect detection and root cause analytics
- Digitize CNC operations with job/operator logging and mobile dashboards
- Increase productivity by optimizing operator efficiency and scheduling
- Provide affordability via a SaaS-based pricing model for cost-sensitive MSMEs

---

3. Industry Pain Points

Problem	Why It Hurts
❌ No real-time visibility	Owners don't know machine status
❌ Manual downtime logs	Leads to inaccurate reporting
❌ Unplanned breakdowns	Production delays, high costs
❌ Poor defect tracking	Defects discovered late → scrap
❌ No predictive maintenance	Failures without warning
❌ Unknown OEE (Overall Equipment Effectiveness)	Inefficient resource utilization

---

4. Proposed Solution – CNCMate

Core Modules

1. Live CNC Monitoring – Real-time status (ON/OFF/IDLE), cycle time, spindle speed, tool usage, temperature, vibration.
2. Predictive Maintenance – AI/ML models forecast tool/machine failures before they occur.
3. Tool Life Monitoring – Remaining tool life prediction & replacement alerts.
4. Defect Detection & Analytics – Manual + AI-based defect tracking, visual inspection, failure pattern recognition.
5. Job & Operator Tracking – Link operators to machines, jobs, and productivity.
6. Dashboards & Reports – Centralized dashboards, auto shift reports (Excel/PDF).
7. Cost Estimation (Phase 2) – Per-job costing using energy, wear, and time data.

---

5. System Architecture

Workflow:

```
CNC Machines → Sensors/PLC → Edge Device (Raspberry Pi) → MQTT/OPC-UA → Backend APIs (FastAPI/Python)
      ↓
 Database (PostgreSQL/InfluxDB) ← Data Pipelines (ETL/Streaming/Kafka)
      ↓
 Dashboards (Streamlit/React/Flutter) ↔ AI/ML Models (Anomaly Detection, Forecasting)
      ↓
 Reports / Alerts (Power BI, Grafana, WhatsApp/Email)
```

Tech Stack:

- Languages: Python, SQL
- Databases: PostgreSQL, InfluxDB
- ML/AI: Scikit-learn, XGBoost, Prophet, PyTorch
- Frameworks: FastAPI, Streamlit, React, Flutter
- Protocols: MQTT, OPC-UA, Modbus TCP
- DevOps: Docker, GitHub Actions, NGINX

---

6. Methodology & Development Timeline (3 Months Plan)

Phase	Duration	Activities & Deliverables
Phase 0 – Planning & Research	Weeks 1–3 (3 weeks)	Use cases, mock dashboards, MSME interviews
Phase 1 – Data Acquisition Layer	Weeks 4–5 (2 weeks)	Edge devices, IoT integration, machine signals
Phase 2 – Backend & Data Layer	Weeks 6–7 (2 weeks)	Databases, ETL pipelines

Phase	Duration	Activities & Deliverables
Phase 3 – Analytics & AI/ML Features	Weeks 8–9 (2 weeks)	OEE, downtime patterns, predictive models
Phase 4 – Dashboards	Weeks 10–11 (2 weeks)	Real-time monitoring dashboards
Phase 5 – Deployment & Testing	Week 12 (1 week)	MVP deployment (local/cloud)
Phase 6 – Business Model & Documentation	Ongoing across project	Pricing, MSME outreach, reports, final documentation

---

7. Use Cases

1. Predictive Maintenance – Forecast spindle/tool failures 3–5 days in advance.
2. Tool Life Prediction – Suggest optimal replacement time for tools.
3. Defect Detection – AI models classify part defects (OK/Minor/Major).
4. Shift Monitoring – Plant managers track live production and idle times.
5. Operator Traceability – Owners check who handled each job, with cost and duration.
6. Job Cost Estimation – (Phase 2) Automated costing for better client quotations.

---

8. Business Model

- Pricing Options:
    - ₹799–₹1,999 per machine/month (SaaS subscription)
    - ₹25,000 setup + training fee
    - ₹50,000 annual license (optional)
- Revenue Streams:
    - SaaS subscription
    - Installation & setup services
    - Add-on predictive modules
    - Annual maintenance contracts
- Target Users: MSME owners, plant managers, supervisors, QA and maintenance teams.

---

9. Statistical & Expected Impact

- ⏱️ 20–30% reduction in unplanned machine downtime
- 🔳 15–20% reduction in part defects via better defect tracking

- 💰 10–15% cost savings through optimized job costing & preventive maintenance
- 📈 Higher productivity with operator/job traceability and OEE tracking

---

10. Future Enhancements

- AI chatbot assistant for operators
- WhatsApp/SMS downtime alerts
- Visual defect detection using CNN + OpenCV
- Integration with ERP/Tally for costing & inventory
- Energy efficiency & sustainability analytics
- Self-healing adaptive workflows (AI-driven parameter tuning)

---

11. Conclusion

CNCMate represents a comprehensive Industry 4.0 solution for MSMEs in India. It is:

- Affordable – SaaS pricing for cost-sensitive factories
- Scalable – Modular design for future AI/ML integration
- Impactful – Reduces downtime, increases productivity, and improves quality
- Practical – Works with existing CNC setups without expensive upgrades

By enabling data-driven decision-making, CNCMate empowers small and medium manufacturers to compete in the global smart manufacturing ecosystem.

👉 **Note:** "CNCMate" is a temporary/sample product name. The final product name will be adapted as per market demand and user feedback.