**Project Summary – Manufacturing Production Analysis**

**Objective**

The goal of this project was to analyze a manufacturing production dataset to identify production trends, defect patterns, cost efficiency, and profitability across different plants and product categories.

**Data Cleaning & Preparation**

* Converted Date column to proper datetime format.
* Handled missing/invalid values using type conversions (errors='coerce').
* Converted costs and revenue into numeric types for accurate calculations.
* Added new derived metrics:
  + **Defect Rate (%) = (Units\_Defective / Units\_Produced) × 100**
  + **Profit = Revenue – Production\_Cost**
* Ensured categorical fields (Plant\_ID, Product\_ID, Product\_Category) were properly encoded.

**Exploratory Data Analysis (EDA)**

* **Production Trends:** Overall production showed fluctuations across months, with defective units also rising proportionally in high-production periods.
* **Defect Rate Comparison:** Certain plants consistently had higher defect rates, especially in specific product categories.
* **Downtime vs Production:** A clear negative correlation was observed — higher machine downtime was associated with lower units produced.
* **Profitability Analysis:** Top 5 most profitable products were identified, with clear dominance by specific product lines.

**Visualizations**

* **Line Chart:** Production vs. Defective Units trend over time.
* **Bar Chart:** Profit comparison across product categories.
* **Heatmap:** Correlation between key numerical features (Production, Defects, Downtime, Labor Hours, Costs, Revenue,

**1. Production & Defective Units Over Time**

* Units produced remain high and fluctuate between ~500 and 2000 units daily.
* Defective units remain consistently lower (mostly under 150), showing a relatively stable defect count.
* No major increasing trend in defects, suggesting quality control is reasonably steady.

**2. Defect Rate by Plant**

* **Plant A** has the highest defect rate (~7.5%).
* **Plant C** is moderate (~6.9%).
* **Plant B** has the lowest defect rate (~6.5%).
* The difference between plants is not very large but could indicate process or workforce efficiency differences.

**3. Machine Downtime vs Units Produced**

* Scatter plot shows **no strong correlation** between downtime and production.
* Plants may have redundancy or buffer systems that mitigate downtime impact.

**4. Profit by Product Category**

* **Automotive** is the most profitable category (~13.5M).
* **Electronics** follows (~11.9M).
* **Textile** is moderate (~10M).
* **Chemicals** generates the least profit (~7.3M).
* Suggests prioritizing investment in **Automotive and Electronics** while reviewing **Chemicals** operations for cost optimization.

**5. Correlation Analysis (Heatmap)**

* **Units Produced vs Defect Rate**: Negative correlation (-0.49) → Higher production tends to reduce defect rate (likely efficiency at scale).
* **Units Defective vs Defect Rate**: Strong positive correlation (0.77) → Expected, as more defective units raise the defect rate.
* **Production Cost & Revenue**: Strong correlation (0.92) → Higher costs generally bring higher revenue.
* **Revenue & Profit**: Moderate correlation (0.43) → Profitability is not solely dependent on revenue; cost management plays a big role.
* Machine downtime and labor hours show weak correlations with major KPIs, meaning other factors (materials, process efficiency) matter more.

**Key Insights**

* Plants differ slightly in defect rates, with **Plant A needing attention**.
* **Automotive and Electronics** are driving profitability, while **Chemicals underperforms**.
* **Defect rate improves with higher production**, indicating efficiency gains at scale.
* **Machine downtime has little effect on output**, suggesting robust mitigation strategies.
* Cost control is crucial since revenue does not guarantee high profits.

**Recommendations**

* Investigate **Plant A’s higher defect rate** with process audits.
* Re-evaluate the **Chemicals division** for cost reduction or strategy shift.
* Continue scaling **Automotive & Electronics** production for maximum profit.
* Optimize cost structures since **profit is not strongly tied to revenue growth**.
* Maintain robust downtime mitigation strategies that are keeping production stable.
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