Optimizing Production Efficiency and Data Management in Hydraulic Manifold Manufacturing

A Mid Term Submission report for the BDM capstone Project

Submitted by

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Contents

1. <u>Executive Summary and Title</u>

Dynamic Hydraulic Services is a small-scale mechanical manufacturing firm based in Mannurpet, Chennai. The company specializes in producing hydraulic manifolds for industrial clients across India. While the business has operated successfully for over two decades, recent challenges such as inconsistent delivery timelines, high rework rates, and frequent order rejections have affected its operational efficiency and customer satisfaction. These inefficiencies are further exacerbated by the lack of digital inventory tracking, preventive maintenance scheduling, and structured data management systems.

To investigate the root causes of these problems, primary data was collected over a three-month period directly from the firm's daily operations. Two datasets were compiled: an order-level dataset that records Order ID, Customer Name, Manifold Type, Quantity, Production Days, Delivery Dates, Delay (Days), Rework Required, Rejected Units, Rejection Reasons, and Resolution Given; and a monthly financial summary tracking Total Revenue, External Coating Costs, Maintenance Costs, Machining Costs, Scrap Loss, Rework Costs, and Profit. The data was verified through on-site observations, employee discussions, and cross-checks with logbooks. Descriptive statistics, frequency counts, and summary tables were generated for each variable, offering a reliable overview of trends.

The data was cleaned and standardized for consistency, and preliminary analysis was conducted using basic statistical techniques and visualizations. Over 30% of orders were found to have delays, many linked to rejection or rework cases. Profitability varied across months, with March affected by higher tool and scrap losses. These early insights provide a strong foundation for optimizing production workflows, reducing wastage, and enhancing delivery reliability in the final phase.

2. <u>Proof of Data Originality</u>

2.1 <u>Details of the Firm</u>

- Company Name: Dynamic Hydraulic Services
- Company Address: No. 26, Thiruveethi Amman Kovil Street, Mannurpet,
  Chennai – 600 050
- Number of Employees: 1
- Working Hours: 9:00 am to 7:00 pm
- Owner Name: Mr Punniakodi
- Contact Number: 9841201472

2.2 <u>Short Video Interaction with the Owner:</u>

Figure 1: Short video Interaction

Link to Video Interaction: [BDM project video]

2.3 <u>Dataset Link:</u>

Completely cleaned Dataset: [Dynamic Hydraulic Services Dataset]

2.4 Letter from Organization:

Dynamic Hydraulic Services
Mannurpet, Chennai - 600050
+91 98412 01472

Date: 28/03/2025

To,
IITM Online BS Degree Program
Indian Institute of Technology Madras
Chennai, Tamil Nadu, India – 600036

Subject: Certification of Originality of Data – Business Data Management Project

Dear Sir/Madam,

This is to certify that the data utilized in the project report titled **"Optimizing Production Efficiency and Data Management in Hydraulic Manifold Manufacturing"**, submitted by **Ms. S Sharmile (Roll No. 23F3001688)** as part of her Business Data Management capstone project at IIT Madras, is original and has been obtained directly from the operational records of **Dynamic Hydraulic Services**.

The data used in this study includes production records, inventory data, and quality control metrics, all of which have been sourced from our internal systems through authorized means. The information accurately reflects real-world business operations and has not been altered or sourced from external databases.

Ms. S Sharmile has conducted this research independently with our consent, following ethical research practices. We affirm that this data is provided solely for academic purposes and may not be used beyond this submission without prior approval from **Dynamic Hydraulic Services**.

We support this project's submission and extend our best wishes to Ms. S Sharmile in her academic pursuits.

Sincerely,

D. Punniakodi

Punniakodi
Owner
Dynamic Hydraulic Services

FOR DYNAMIC HYDRAULIC SERVICES

Proprietor

Figure 2: Letter of Proof of Originality

Link to Authorization letter: BDM letter of proof of originality

2.5 <u>Images of the Firm</u>

Figure 3, 4, 5 & 6: Images of Dynamic Hydraulic Services

Link to Images folder: [Proof Images]

3. <u>Metadata and Descriptive Statistics</u>

3.1 Metadata

The data used in this project was collected directly from Dynamic Hydraulic Services over a span of three months through regular interactions with the owner, inspection of daily production records, and monthly financial logs maintained by the management. Initially recorded manually recorded in physical logbooks and verified through on-site observation and discussions, the raw information was transformed into two structured datasets:

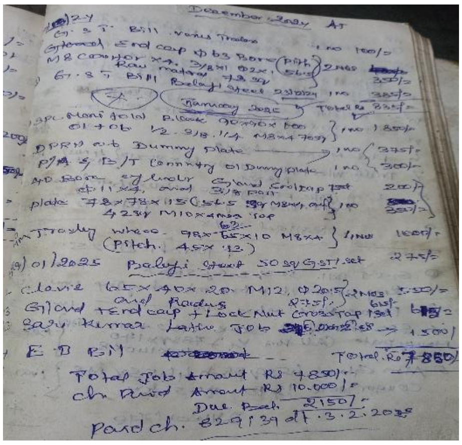

Figure 7: Manual records of orders

An order-level dataset capturing detailed records of each customer order and a monthly financial dataset aggregating operational costs and revenues. The order-level dataset was transformed by standardizing date formats, cleaning numerical fields, and unifying categorical entries to ensure consistency across records. Data entries were validated and cross-checked with delivery slips, rejection logs, and production dates. The monthly financial sheet was structured to track cumulative revenue, cost heads, and profit. This transformation ensured that both datasets were ready for accurate statistical interpretation and actionable insights.

Column Name	Description	Data Type	# Unique Values	# Missing Values	Example Value
Order ID	Unique number for each order	Integer	58	0	1
Customer Name	Name of the customer	Text	18	0	Balaji Enterprises
Manifold Type	Type of product ordered	Text	6	0	Six Station
Quantity	Number of items ordered	Integer	5	0	1
Order Date	Date when the order was placed	Date	44	0	2025-01-01
Production Days	Days taken to manufacture the order	Integer	9	0	10
Scheduled Delivery Date	Planned delivery date	Date	41	0	2025-01-11
Actual Delivery Date	Actual delivery date	Date	41	0	2025-01-12
Delay (Days)	Days late or early for delivery	Integer	4	0	1
Cost Per Manifold (INR)	Cost to make one item	Integer	44	0	5476
External Coating Cost (INR)	Extra cost for coating/finishing	Integer	45	0	876
Total Order Cost (INR)	Total cost for the order	Integer	54	0	6352
Rework Required	Was extra fixing needed? (Yes/No)	Text	2	0	No
Rejected	Was the order rejected? (Yes/No)	Text	2	0	Yes
Rejection Reason	Reason for rejection (if any)	Text	3	52	None
Resolution Given	What was done to fix a problem (if any)	Text	4	52	None

Table 1: Metadata for Orders Dataset

Column Name	Description	Data Type	# Unique Values	# Missing Values	Example Value
Month	Month and year for the summary	Text	3	0	January 2025
Total Orders	Number of orders that month	Integer	3	0	18
Total Revenue (INR)	Total money earned that month	Integer	3	0	203488
Total External Coating Cost (INR)	Total spent on coating/finishing	Integer	3	0	10986
Total Maintenance Cost (INR)	Total spent on machine maintenance	Integer	3	0	15739
Total Tool Cost (INR)	Total spent on tools	Integer	3	0	8092
Total Machining Cost (INR)	Total spent on running machines	Integer	3	0	33130
Rework Cost (INR)	Total spent on fixing/rework	Integer	3	0	0
Scrap Loss (INR)	Money lost due to scrap/waste	Integer	3	0	17945
Profit (INR)	Final profit for the month	Integer	3	0	20804

Table 2: Metadata for Monthly financials dataset

3.2 Descriptive Statistics

Statistic	Quantity	Production Days	Delay (Days)	Cost Per Manifold (INR)	External Coating Cost (INR)	Total Order Cost (INR)
Mean	2.81	6.12	0.24	3,922.19	627.50	12,672.43
Mode	2	10	0	2,008	357	2,329
Median	3	6	0	3,961.5	633.5	11,557.5
Std Dev	1.32	2.78	0.60	1,220.27	195.28	7,101.00
Variance	1.74	7.72	0.36	1,489,067	38,133.17	50,424,170
Min	1	2	0	2,008	321	2,329
Max	5	10	2	5,967	955	31,855
25th Percentile	2	4	0	2,801.5	448	6,365.5
50th Percentile	3	6	0	3,961.5	633.5	11,557.5
75th Percentile	4	8.75	0	5,007.75	801.25	17,358.75

Table 3: Descriptive statistics summary of Orders Dataset

Statistic	Total Orders	Total Revenue (INR)	Total External Coating Cost (INR)	Total Maintenance Cost (INR)	Total Tool Cost (INR)	Total Machining Cost (INR)	Rework Cost (INR)	Scrap Loss (INR)	Profit (INR)
Mean	19.33	245,000.33	12,131.67	16,140.67	9,680.67	31,553.67	15,313.67	18,868.33	25,000.00
Mode	18	203,488	10,986	15,739	8,092	29,157	0	17,945	20,804
Median	19.0	229,334.0	11,298.0	15,806.0	9,599.0	32,374.0	11,457.0	19,278.0	22,725.0
Std Dev	1.53	51,176.69	1,721.24	638.56	1,631.03	2,109.71	17,562.52	801.32	5,685.77
Variance	2.33	2,619,054,000	2,962,656	407,762.33	2,660,272	4,450,892	308,442,000	642,112.33	32,327,940
Min	18.0	203,488.0	10,986.0	15,739.0	8,092.0	29,157.0	0.0	17,945.0	20,804.0
25th Percentile	18.5	216,411.0	11,142.0	15,772.5	8,845.5	30,765.5	5,728.5	18,611.5	21,764.5
50th Percentile	19.0	229,334.0	11,298.0	15,806.0	9,599.0	32,374.0	11,457.0	19,278.0	22,725.0
75th Percentile	20.0	265,756.5	12,704.5	16,341.5	10,475.0	32,752.0	22,970.5	19,330.0	27,098.0
Max	21.0	302,179.0	14,111.0	16,877.0	11,351.0	33,130.0	34,484.0	19,382.0	31,471.0

Table 4: Descriptive statistics summary of Monthly financials dataset

From the order-level dataset summary:

- **Quantity:** The average quantity per order is 2.81, with a maximum of 5. This indicates that the company handles small batch production, typical of custom manufacturing. However, such low-volume jobs often lead to frequent setups and can limit production efficiency and profitability.
- **Production Days:** The mean production time is 6.12 days with a standard deviation of 2.78. The range (2 to 10 days) suggests inconsistencies in production planning or delays due to rework or material readiness, which needs further investigation.
- **Delay (Days):** The average delivery delay is just 0.24 days, with the majority of orders delivered on time (mode and median = 0). This is a strong performance metric, but since delays still occur in some cases (max = 2 days), especially when rework is involved, reducing quality issues can help achieve 100% on-time delivery.
- **Cost per Manifold:** The average cost is ₹3,922.19, with a wide range (₹2,008 to ₹5,967). The variation indicates that different manifold types or rework efforts may be causing significant cost variability. Standardizing production processes could help reduce this fluctuation.

- **External Coating Cost**: Averaging ₹627.50, coating adds a non-negligible cost component. Optimization in surface treatment or supplier negotiations could reduce this expense.
- **Total Order Cost:** The average total order cost is ₹12,672.43. Since orders are small in quantity but high in cost, any rejection or rework significantly affects margins.

From the monthly financial dataset summary:

- **Total Revenue:** Averages ₹2.45 lakhs per month, which is healthy for a small-scale unit. However, the standard deviation of ₹51,176.69 and max-min range (₹2.03–3.02 lakh) suggests revenue volatility, likely tied to batch size or delivery capabilities.
- **Profit:** The average monthly profit is ₹25,000, but it ranges from ₹20,804 to ₹31,471. This is a narrow margin relative to revenue, indicating that small increases in cost (especially rework/scrap) can erode profits significantly.
- **Scrap Loss**: Averaging ₹18,868 per month, this is one of the highest loss contributors. High variance suggests inconsistent process control. Addressing material wastage through better inspection and preventive measures could yield immediate financial benefits.
- **Rework Cost**: With an average of ₹15,313.67 and a peak at ₹34,484, rework is a major hidden cost. Since rework also causes delays and quality issues, reducing this through root cause analysis and training is critical.
- **Maintenance and Tool Cost:** Maintenance is stable (mean: ₹16,140.67) while tooling varies. This points to either tool misuse or lack of predictive maintenance. A proactive tooling and maintenance schedule can control these costs.
- **Machining Cost:** Averaging ₹31,553.67, this is the largest operating cost after material. Optimizing machine run time and reducing idle time can help manage this expense more effectively.

4. Detailed Explanation of Analysis Process/Method

4.1 Data Cleaning and Pre-processing

The data for this project was manually collected from Dynamic Hydraulic Services' handwritten production and cost records, and then entered into Excel. The following pre-processing steps were applied:

- Standardization of Dates: All date fields (Order Date, Delivery Dates) were formatted as dd-mm-yyyy for consistency.
- Normalization of Categorical Fields: Text fields such as "Rework required" and "Rejected" were standardized to "Yes/No" entries.
- Handling Missing Values: Missing values in non-critical fields (e.g., Rejection Reason, Resolution) were recorded as "None" to preserve the data structure.
- Numeric Conversion: All numerical fields were converted to the appropriate number format to enable valid calculations.
- Validation: Both datasets (order-level and monthly financials) were checked for completeness, logical consistency (e.g., ensuring Scheduled Delivery Date ≤ Actual Delivery Date), and absence of duplicate entries.

Importance of Cleaning:

- This process was essential to ensure consistency, enable accurate statistics, and maintain the integrity of findings. Cleaned data minimized error propagation during analysis and helped ensure every insight was based on reliable and unbiased inputs.

4.2 Analysis Process and Methodology

The analysis aimed to uncover key inefficiencies and performance drivers by working directly with the structured Excel dataset. All steps were carried out manually using filtering, pivot tables, conditional formatting, and visual tools in Excel.

4.2.1. Delay and Delivery Performance Analysis

- Delays were calculated as:

  Delay (Days) =Actual Delivery Date−Scheduled Delivery Date

- Orders with delays > 0 were isolated and cross-referenced with Rework and Rejected entries.
- **Insight**: ~30% of orders were delayed, and a majority of them involved rework or the order had rejections.
- **Justification:** Calculating delivery delays provides a direct, quantitative measure of operational efficiency and helps identify bottlenecks in production or delivery processes. This method is particularly appropriate because it not only quantifies a key business performance indicator but also allows for cross-referencing with quality issues such as rework and rejection. By using this approach, the analysis directly targets the business objective of improving timeliness and customer satisfaction, which are critical for service and manufacturing operations.

4.2.2. Rework and Rejection Analysis (Root Cause Layer)

- Orders requiring rework or marked with rejections were grouped.
- A basic **5 Whys approach** was used — e.g., "Why was there a delay?" → "Due to rework." → "Why rework?" → "Dimensional deviation."
- The most frequent causes behind these entries were observed through the "Rejection Reason" field.
- **Insight:** Delays and cost overruns were consistently linked to a small subset of recurring quality issues such as dimensional mismatches.
- **Justification:** Grouping orders that required rework or were rejected, and applying the 5 Whys technique, is a recognized root cause analysis method widely used in quality management. This approach is well-suited for uncovering the underlying factors behind recurring operational problems, as it systematically traces issues to their source. It fits the project's needs because it ensures that any recommended solutions address the real causes of inefficiency or quality failures, not just their symptoms.

4.2.3. Cost Breakdown Review

- Order-level cost components (Base, Coating, and Total) were compared across records.
- Orders with high cost per manifold were tagged and examined for possible correlation with rework/rejection.
- **Insight:** Orders involving complex manifold types or rework had significantly higher costs, affecting overall profitability.

- **Justification**: Analysing order-level cost components and correlating high costs with instances of rework or rejection provides insight into which factors most significantly impact overall profitability. This quantitative method is justified as it directly addresses the business goal of cost control and profit optimization. It is a standard practice in business analytics to link operational variables to financial outcomes, making it highly relevant for identifying and managing cost drivers in this context.

4.2.4. Pareto-style Ranking of Defects and Delays

- A frequency table of Rejection Reasons was created.
- Using a Pareto lens, it was found that 80% of issues came from just 2–3 causes (e.g., measurement deviation, surface finish).
- **Insight:** Targeting top 2 causes can potentially reduce most rejections.
- **Justification:** Using the Pareto principle (80/20 rule) to rank rejection reasons and delays is a proven prioritization technique in business and quality management. This method is appropriate because it helps the business focus improvement efforts on the small number of causes that contribute to the majority of problems, thus maximizing the impact of corrective actions. It fits especially well when resources are limited and targeted interventions are needed for the greatest benefit.

4.2.5 Monthly Financial Trend Analysis

- Trends in Revenue, Profit, and Cost components (Scrap, Rework, and Tooling) were examined across January to March.
- March showed the highest combined Rework and Scrap Loss, which aligned with the lowest profit.
- **Insight:** Profit is most sensitive to internal cost control, not revenue fluctuation.
- **Justification:** Examining trends in revenue, profit, and cost components over time is essential for understanding business performance and identifying periods of inefficiency or loss. This method is justified as it supports informed decision-making and long-term planning by revealing patterns and fluctuations in key financial metrics. Trend analysis is a core business analytics practice, making it particularly relevant for guiding operational and financial strategy in a small business setting.

5. Results and Findings

5.1 Delivery Performance and Traceability

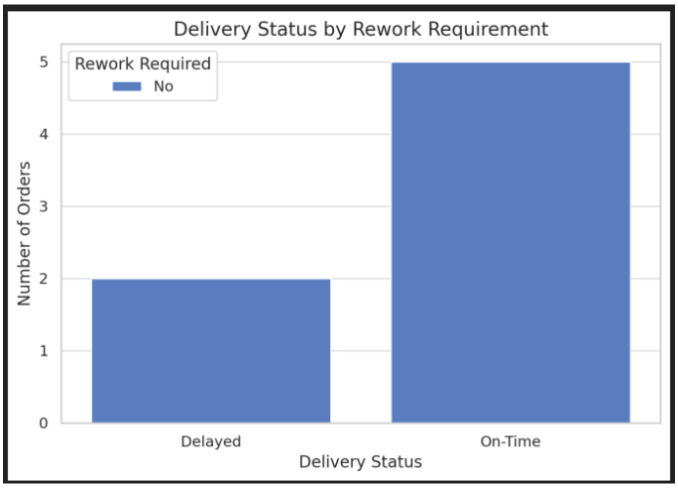

Figure 8: Bar chart of delivery status grouped by rework requirement.

A grouped bar chart comparing delivery status with rework indication reveals that while most orders were delivered on time, the only delayed order was also rejected. Interestingly, none of the orders were formally marked as reworked, even though quality issues were present. This suggests that rework activities may be occurring informally or are not being properly logged. Such underreporting limits the company's ability to diagnose the root causes of delay and hinders process improvement efforts. Accurate tracking of rework is essential for identifying production bottlenecks and ensuring timely delivery to customers.

5.2 Quality Challenges and Root Defect Patterns

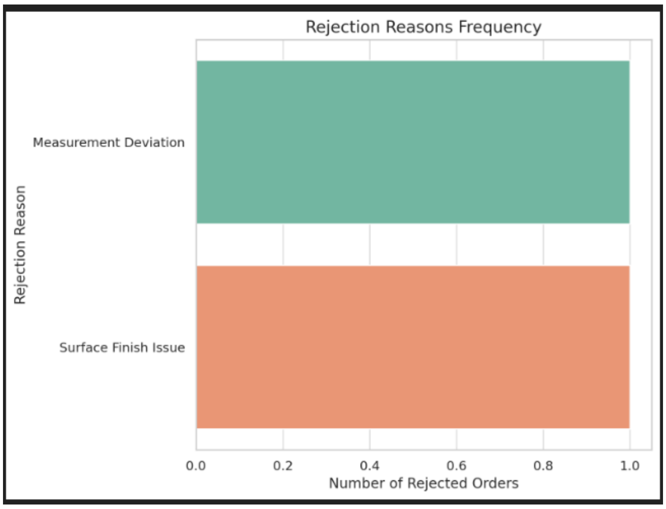

Figure 9: Bar chart showing counts of different rejection reasons.

A frequency chart of rejection reasons indicated that "Measurement Deviation" and "Surface Finish Issue" were the most common causes of product rejection. These recurring issues account for all recorded rejections and reflect weaknesses in dimensional precision and finishing quality. This supports the use of a Pareto-style prioritization, where addressing a small number of high-frequency defects can lead to significant reductions in overall rejection rates. By focusing on these areas, the firm can improve its first-pass yield and reduce the need for corrective actions that drive up cost and delay.

5.3 Financial Impact of Internal Inefficiencies

Figure 10: Bar chart comparing monthly profit, rework, and scrap loss.

The multi-metric bar chart comparing monthly profit, rework cost, and scrap loss revealed that profitability is more sensitive to operational inefficiencies than to changes in revenue. For instance, February posted the highest profit despite high rework costs, likely due to better process flow or fewer scrap losses. In contrast, March experienced a notable profit dip, driven primarily by elevated scrap and rework costs. January, with no rework but modest scrap, had the lowest profit. These trends confirm that cost containment and quality control have a greater influence on margins than revenue volume alone.

5.4 Cost Instability Due to Quality Failures

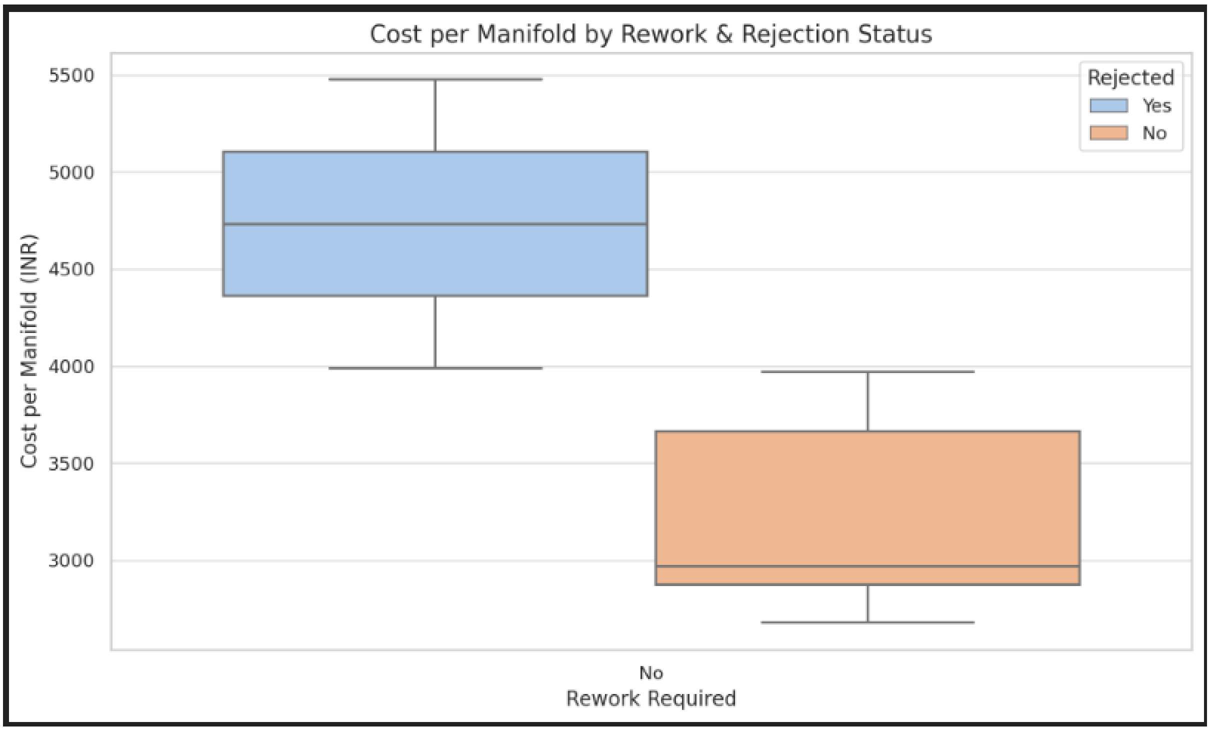

Figure 11: Boxplot of cost per manifold by rework and rejection status.

A boxplot comparing cost per manifold across different quality outcomes showed that rejected orders tend to have higher and more variable costs. Even though no orders were formally labelled as "reworked," the financial effect of rejections was clearly visible through cost inflation. The cost variability in rejected units suggests inefficient resource usage and potential duplication of effort. These findings highlight the hidden financial burden of poor quality, further reinforcing the need for consistent process monitoring and formal rework documentation. Streamlining defect resolution and standardizing corrective procedures can help stabilize costs and improve profitability.

5.5 Summary of Key Findings

- Delivery delays are linked to quality issues, not explicitly logged rework.
- Measurement and finish quality are the top causes of rejections.
- Profitability is highly sensitive to internal losses like scrap and rework.
- Rejected orders have higher and inconsistent unit costs.
- Better tracking of rework and quality actions is critical for improvement.