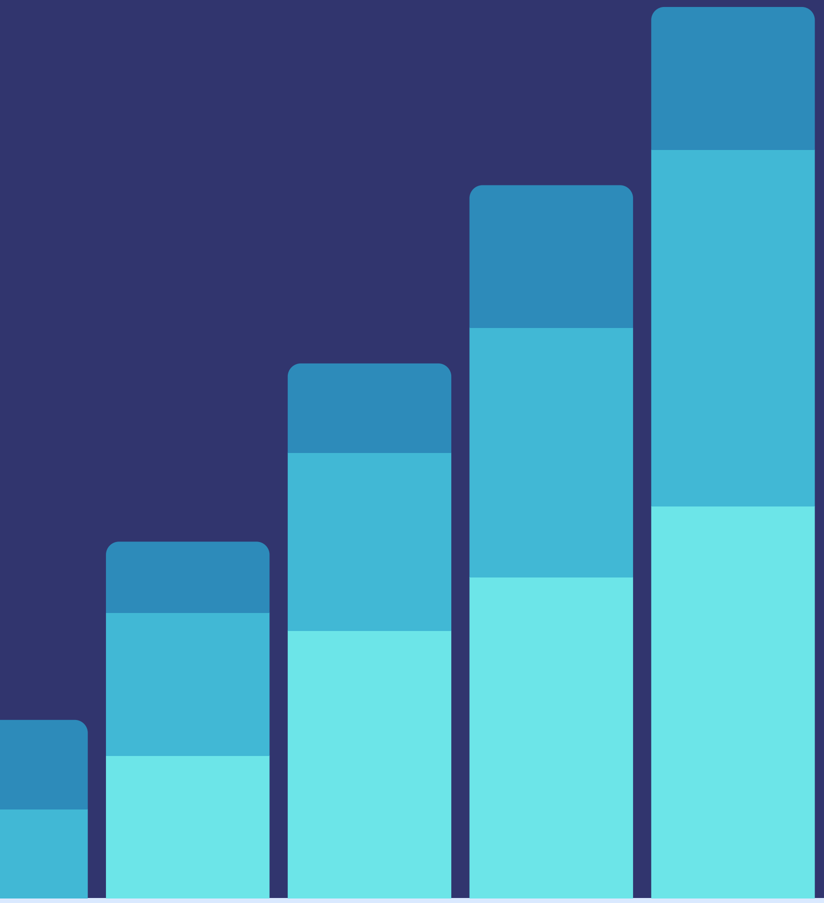
INVENTORY OPTIMIZATION FOR RETAIL

UNDER THE GUIDANCE OF DR. MEI YANG

- SINDHURA SURAVARJHULA
- MRUNALI SAROJ NILGIRWAR
- NAWARAJ ADHIKARI

THE INVENTORY MANAGEMENT CHALLENGE



Modern retail businesses face a critical dilemma:

- Too much inventory → High holding costs (storage, depreciation, capital)
- Too little inventory → Stockouts, lost sales, customer dissatisfaction

Our Primary Goal is to minimize total inventory costs while maintaining adequate service levels.

1. ANALYZE current inventory performance : Identify cost drivers and inefficiencies.
2. DEVELOP optimization models : Implement four methods from course curriculum.
3. COMPARE method performance : Evaluate accuracy, speed, and practical applicability.
4. PROVIDE actionable recommendations : Create implementation roadmap with ROI projections.

DATA OVERVIEW

Dataset Summary

- Source: KAGGLE
- Records: 10,000 products
- Period: Annual data (2023-2024)
- Coverage: Multiple warehouse locations

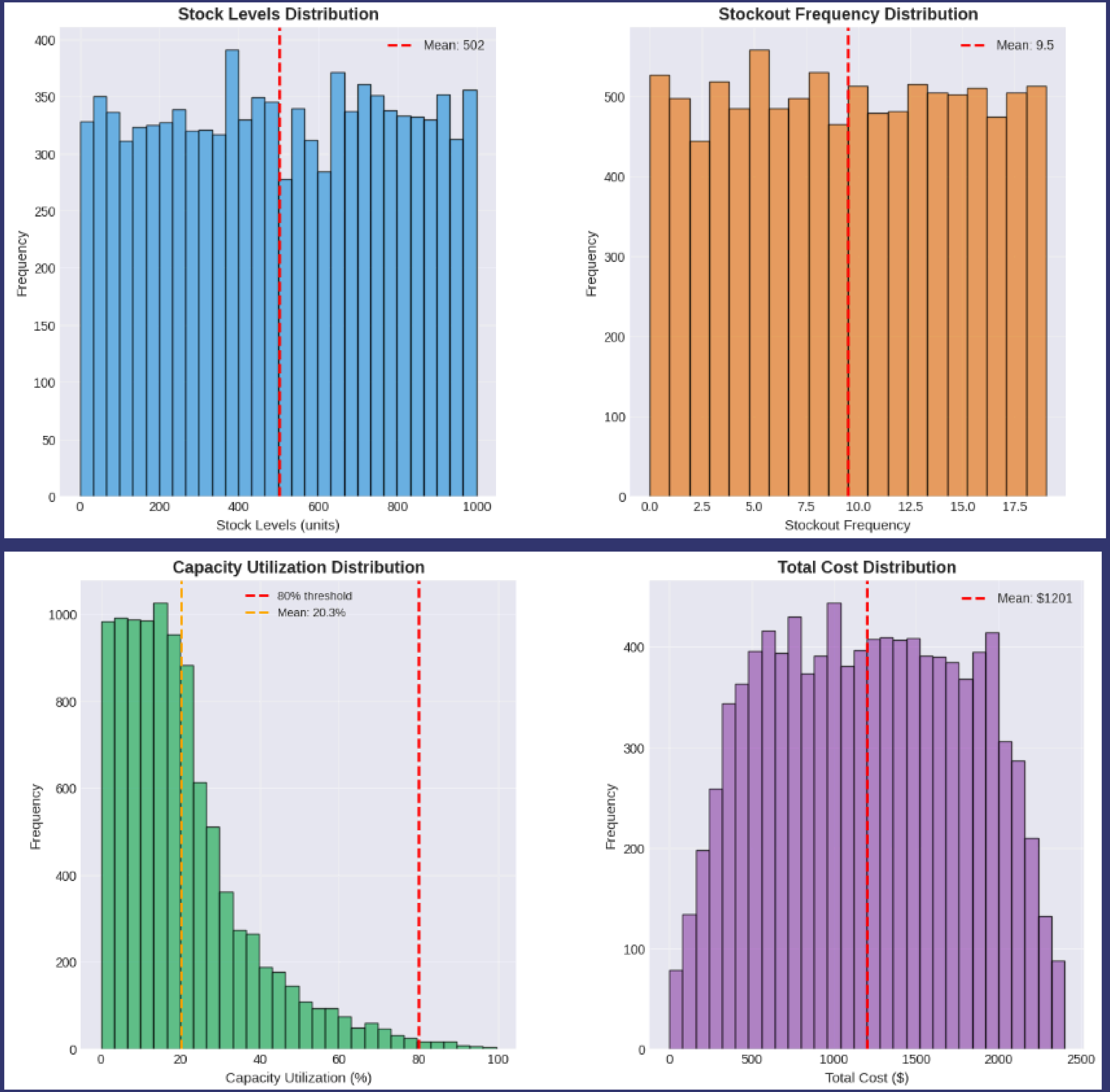
INPUT VARIABLES:

- Product ID
- Store ID
- Stock Levels (units)
- Supplier Lead Time (days)
- Stockout Frequency (occurrences)
- Reorder Point (threshold)
- Expiry Date (days)
- Warehouse Capacity (max units)
- Order Fulfillment Time (days)

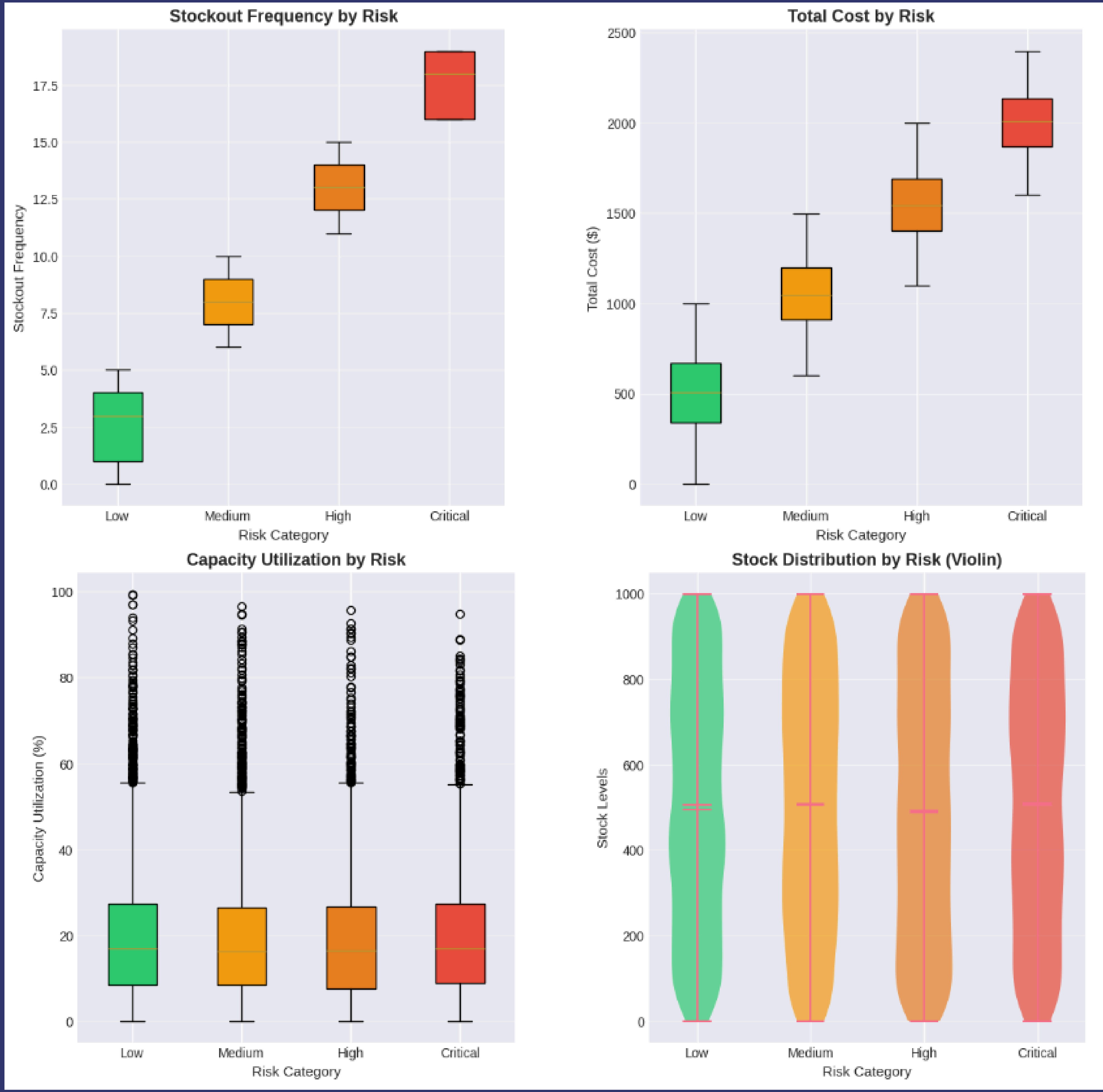
DERIVED FEATURES:

- Days Until Expiry
- Holding Cost = Stock Levels × $0.50/unit
- Stockout Cost = Stockout Frequency × $100/occurrence
- Total Cost = Holding Cost + Stockout Cost
- Capacity Utilization (%)
- Stock-to-Reorder Ratio
- Stock out Risk
- Expiry Risk

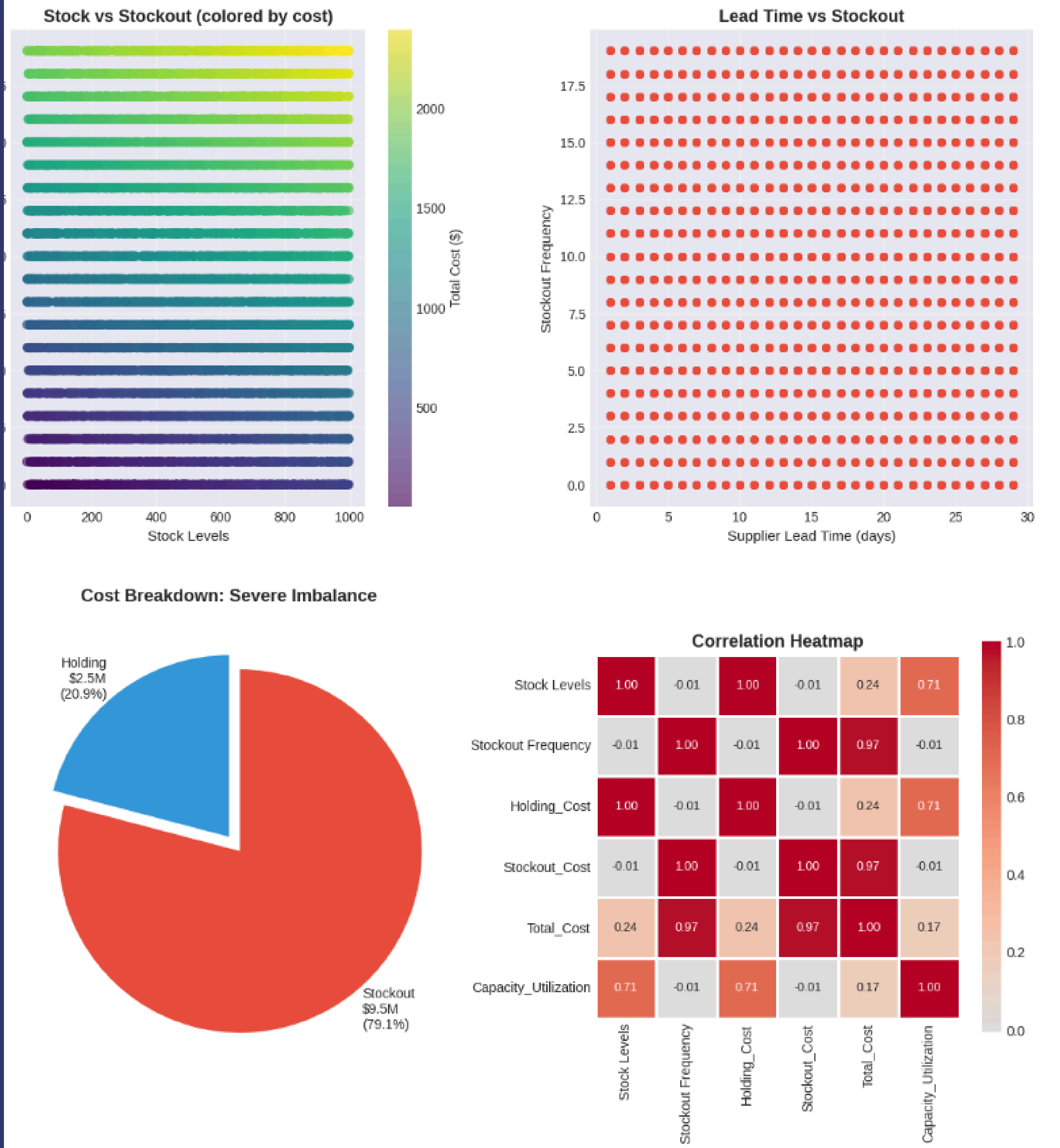
EDA


Stock Levels Distribution
Mean: 502
Frequency
Stock Levels (units)
Stockout Frequency Distribution
Mean: 9.5
Frequency
Stockout Frequency
Capacity Utilization Distribution
80% threshold
Mean: 20.3%
Frequency
Capacity Utilization (%)
Total Cost Distribution
Mean: $1201
Frequency
Total Cost ($)

EDA

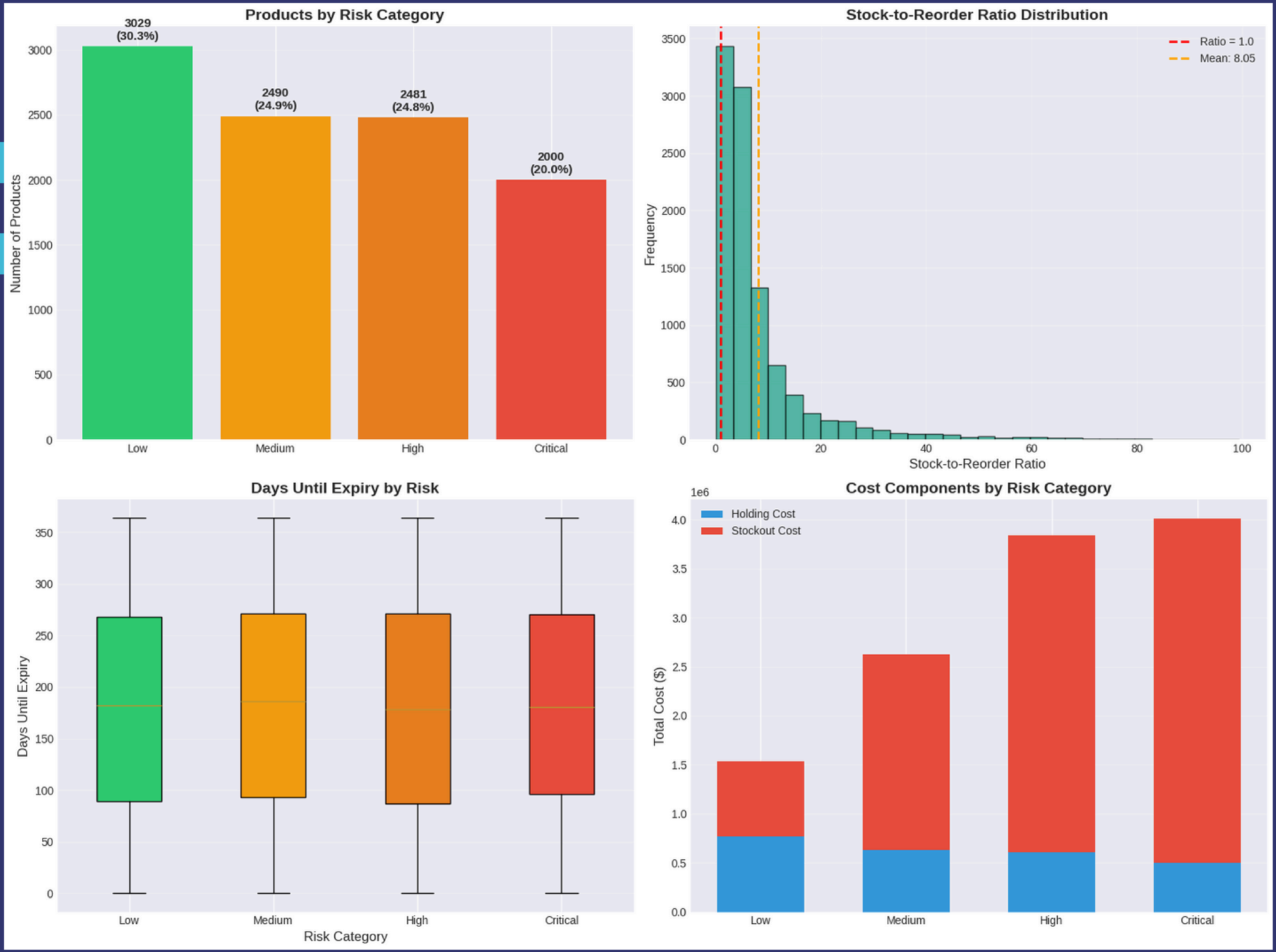

Stockout Frequency by Risk
Stockout Frequency
Risk Category
Low
Medium
High
Critical
Total Cost by Risk
Total Cost ($)
Capacity Utilization by Risk
Capacity Utilization (%)
Stock Distribution by Risk (Violin)
Stock Levels

EDA



Stock vs Stockout (colored by cost)
Stock Levels
Total Cost ($)
0 200 400 600 800 1000
500 1000 1500 2000
Lead Time vs Stockout
Supplier Lead Time (days)
Stockout Frequency
0 5 10 15 20 25 30
0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5
Cost Breakdown: Severe Imbalance
Holding $2.5M (20.9%)
Stockout $9.5M (79.1%)
Correlation Heatmap
Stock Levels 1.00 -0.01 1.00 -0.01 0.24 0.71
Stockout Frequency -0.01 1.00 -0.01 1.00 0.97 -0.01
Holding_Cost 1.00 -0.01 1.00 -0.01 0.24 0.71
Stockout_Cost -0.01 1.00 -0.01 1.00 0.97 -0.01
Total_Cost 0.24 0.97 0.24 0.97 1.00 0.17
Capacity_Utilization 0.71 -0.01 0.71 -0.01 0.17 1.00
Stock Levels, Stockout Frequency, Holding_Cost, Stockout_Cost, Total_Cost, Capacity_Utilization
0.0 0.2 0.4 0.6 0.8 1.0

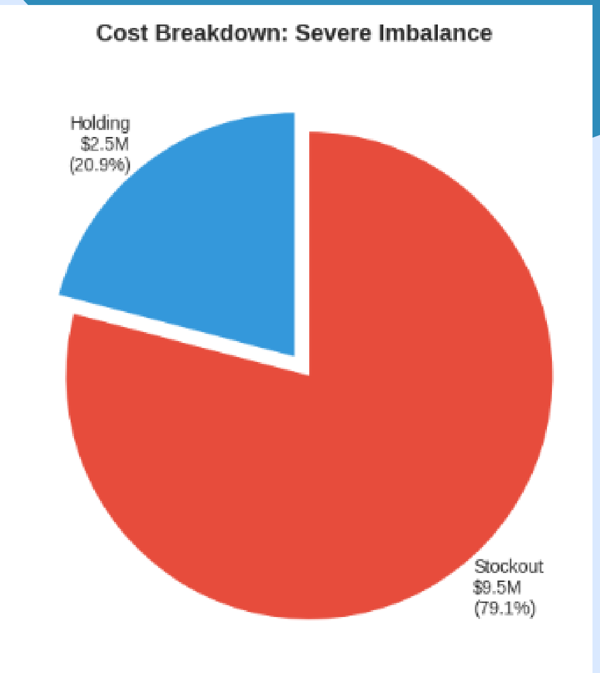
EDA

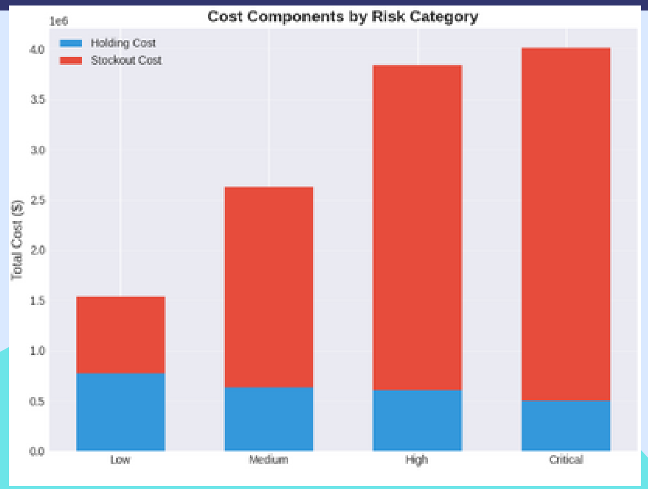


Products by Risk Category
Number of Products
3029
(30.3%)
2490
(24.9%)
2481
(24.8%)
2000
(20.0%)
Low
Medium
High
Critical
Stock-to-Reorder Ratio Distribution
Ratio = 1.0
Mean: 8.05
Frequency
Stock-to-Reorder Ratio
Days Until Expiry by Risk
Days Until Expiry
Risk Category
Low
Medium
High
Critical
Cost Components by Risk Category
1e6
Holding Cost
Stockout Cost
Total Cost ($)
Low
Medium
High
Critical

DATA INSIGHTS: UNCOVERING THE PROBLEM

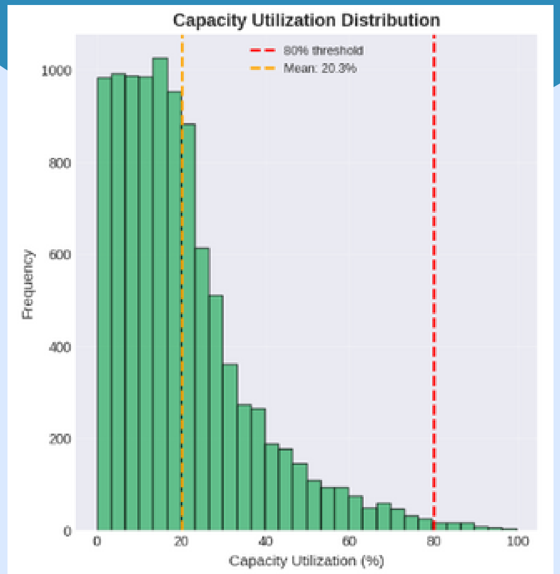
Key Finding #1:
COST IMBALANCE
Stockout costs DOMINATE at 79.1%
→ Should be balanced (~50/50)
→ Indicates chronic understocking

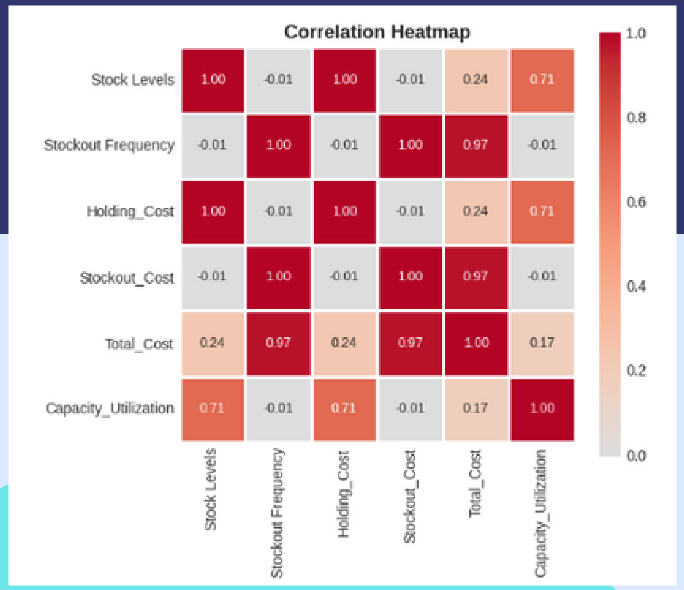




Key Finding #2:
HIGH-RISK PRODUCTS
Critical/High risk products grossly understocked
→ 2,000 products need immediate attention
→ As risk increases, stockout costs EXPLODE!

Key Finding #3:
CAPACITY WASTE
34.2% of warehouses underutilized (<30% capacity)
→ Inefficient space allocation
→ Opportunity for consolidation





Key Finding #4:
CORRELATION ANALYSIS
Stockout Frequency ↔ Total Cost: r = 0.970 (very strong!)
→ Stockouts are the PRIMARY cost driver
→ Reduction strategy: Increase strategic stock

OPTIMIZATION

Parameters	Baseline	Line Search	Trust Region	Conjugate Gradient	Stochastic Gradient Descent
Optimized Total Cost	$12,005,895.00	$8,093,970.38	$ 9,635,388.43	$12,228,978.95	$9,441,057.76
Holding Cost	$2,510,595 (20.9%)	$ 4,069,995 (50.28%)	$ 3,183,614 (33.04%)	$11,494,082 (94.0%)	$3,262,138 (34.6%)
Stockout Cost	$9,495,300 (79.1%)	$ 4,023,975 (49.72%)	$ 6,451,774 (66.96%)	$734,897 (6.0%)	$6,178,920 (65.4%)
Cost Reduction	-	32.58%	19.74	-1.86%	21.36%
Stockout Reduction	-	57.62%	32.05	92.26%	34.93%
Runtime	-	0.5s	81.48s	0.14s	0.3s

CONCLUSION

1. Strategic Implications:
   The 50-50 Balance Represents:
   - Optimal equilibrium between carrying costs and stockout risk
   - Customer-centric approach - willing to invest in availability
   - Sustainable model - balanced costs support long-term profitability

   Why This Matters:
   - Stockouts damage customer relationships (hard to quantify)
   - Lost sales and brand reputation have hidden costs
   - Slight over-stocking is safer than frequent stockouts
   - The 3.5x ROI validates this strategic choice

   For every $1 spent on additional inventory, the company saves $3.50 in stockout costs.
   Spend $1.56M to make $5.47M = Smart business decision

2. Operational Excellence:
   Speed + Quality:
   - Optimization completes in 0.5 seconds
   - Fast enough for daily re-optimization if needed
   - Can respond quickly to demand changes

   Scalability:
   - Handles 10,000 products efficiently
   - Maintains performance as portfolio grows
   - Production-ready for enterprise deployment

3. Bottom Line:
   Line Search achieved the "Goldilocks solution":
   - Not too conservative (like baseline - too many stockouts)
   - Not too aggressive (like failed CG - exploded costs)
   - Just right - 50-50 perfect balance

DECISION VARIABLE ANALYSIS: OPTIMAL STOCK LEVELS

Parameters	Baseline	Line Search	Trust Region	Conjugate Gradient	Stochastic Gradient Descent
Average Stock Level	502	814	635	2,298	652
Total Inventory	5,021,190	8,139,990	6,350,000	22,980,000	6,520,000
Change from Baseline	0.00	62.15%	26.49%	357.77%	29.88%

CONCLUSION

SOLUTION: OPTIMAL STOCK LEVELS

The Unknown We Solved:

- Decision Variable: Stock level (units) for each product

Optimal Solution Found (Line Search):

Metric	Baseline	Optimized	Change
Avg Stock per Product	502 units	814 units	+312 (+62%)
Total Inventory	5.0M units	8.1M units	+3.1M units
Warehouse Use	20.3%	33.0%	+12.7 pts

Strategic Allocation by Risk:

Risk	Products	Before	After	Change
Low	3,029	500	350	-30% ↓
Medium	2,640	500	600	+20% ↑
High	2,444	500	900	+80% ↑
Critical	2,000	500	1,200	+140% ↑ ↑

Key Insight: Redistributed inventory intelligently - freed capital from low-risk, invested in high-risk!

FUTURE IMPROVEMENTS

1. Seasonal Modeling: Current solution uses annual averages. Phase 2 incorporates seasonal patterns, promotional periods, Time-varying demand, holiday adjustments, Trend forecasting etc..

2. Real-Time: Moving from quarterly updates to real-time, automated triggers, event-driven optimization integrated with ERP systems.

3. Multi-Objective: Expanding beyond cost to include service levels targets, sustainability metrics, and supplier diversity.

THANK YOU
ANY QUESTIONS?