

# FeMoaSa Manufacturing & Warehouse Design - Complete Task 1 & 2 Solution Guide

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**Course:** ISyE 6202 & 6335 Fall 2025

**Project:** FeMoaSa Facility Organization Testbed

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## Project Overview

### Objective

Develop for **Year +1 period**:

- **Production capacity plan** to meet demand for all parts
- **Warehouse plan** for finished goods storage (factory + 2 client warehouses)

### Key Constraints

#### Operating Parameters:

- Schedule: 5 days/week, 2 shifts/day, 8 hours/shift
  - Efficiency: 90%
  - Reliability: 98%
  - Effective Availability:  $90\% \times 98\% = 88.2\%$
  - Service Level: 99.5% OTIF (On-Time In-Full)

#### Client Locations & Requirements:

- Client A: 90 miles North, 4-hour buffer autonomy
  - Client B: 110 miles South, 12-hour buffer autonomy

#### Product Line:

- 5 Products: A1, A2, A3 (for Client A), B1, B2 (for Client B)
- 20 Parts: P1 ~ P20
- 13 Processes: A ~ M

## Data Sources and Structure

### CSV File Structure Analysis

#### 1. +1 Year Product Demand.csv

##### File Structure:

```
Row 0: Title (Year +1 Demand Forecast...)
Row 1: Header (Year, A1, A2, A3, B1, B2, Total)
Row 2: Annual demand data
Row 5-7: Standard deviation section
Row 10-12: Weekly demand section
Row 14-16: CV (Coefficient of Variation) section
```

##### Data Extraction Code:

```
product_demand_raw = pd.read_csv('data/csv_outputs/+1 Year Product Demand.csv',
header=None)

# Row 2, columns 2-6: Annual demand
annual_demand_values = product_demand_raw.iloc[2, 2:7].astype(float).tolist()
# → [50000, 100000, 130000, 60000, 80000]

# Row 12, columns 2-6: Weekly demand
weekly_demand_values = product_demand_raw.iloc[12, 2:7].astype(float).tolist()
# → [961.54, 1923.08, 2500.00, 1153.85, 1538.46]

# Row 16, columns 2-6: CV values
cv_values = product_demand_raw.iloc[16, 2:7].astype(float).tolist()
# → [0.15, 0.20, 0.20, 0.12, 0.18]
```

##### Extracted Data:

Product	Annual Demand	Weekly Demand	CV	Weekly Std Dev
A1	50,000	961.54	0.15	144.23
A2	100,000	1,923.08	0.20	384.62
A3	130,000	2,500.00	0.20	500.00

<b>Product</b>	<b>Annual Demand</b>	<b>Weekly Demand</b>	<b>CV</b>	<b>Weekly Std Dev</b>
B1	60,000	1,153.85	0.12	138.46
B2	80,000	1,538.46	0.18	276.92

## 2. +1 Year Parts per Product.csv

### File Structure:

Row 0: Title (Parts per Assembled Product Unit...)  
Row 1: Header (Part, A1, A2, A3, B1, B2)  
Row 2-21: BOM data for P1~P20

### Data Extraction Method (UTF-8 encoding important):

```
bom_lines = []
with open('data/csv_outputs/+1 Year Parts per Product.csv', 'r', encoding='utf-8') as f:
    for line in f:
        bom_lines.append(line.strip().split(','))

# Starting from Row 2, column 1 has part name, columns 2-6 have quantities
for i in range(2, 22): # P1~P20
    part_name = bom_lines[i][1]
    for j, product in enumerate(['A1', 'A2', 'A3', 'B1', 'B2']):
        qty = bom_lines[i][2+j]
        if qty: # If not empty
            bom[part_name][product] = int(float(qty))
```

### BOM Matrix Example (partial):

<b>Part</b>	<b>A1</b>	<b>A2</b>	<b>A3</b>	<b>B1</b>	<b>B2</b>
P1	1	2	4	4	1
P2	4	0	2	2	0
P16	0	1	4	0	0
P18	4	1	0	0	4
P19	0	2	4	4	1
P20	0	2	3	3	0

## 3. Parts Specs.csv

### File Structure:

Row 0-9: Header information  
 Row 10: Process header (Part, Step 1, Step 2, ...)  
 Row 11-30: Process sequences for P1~P20  
 Row 33: Dimensions header (Part, Dimensions, Materials)  
 Row 34: Detail header (Identifier, X, Y, Z, Weight, Price)  
 Row 35-54: Dimension and material info for P1~P20

### Data Extraction Code:

```
parts_specs_raw = pd.read_csv('data/csv_outputs/Parts Specs.csv', header=None)

# Process sequences (Row 11-30)
for i in range(11, 31):
    part_name = parts_specs_raw.iloc[i, 1]
    operations = []
    for j in range(2, 9): # Columns 2-8
        op = parts_specs_raw.iloc[i, j]
        if pd.notna(op):
            operations.append(str(op))
    process_operations[part_name] = operations

# Dimension information (Row 35-54)
for i in range(35, 55):
    part_name = parts_specs_raw.iloc[i, 1]
    part_dimensions[part_name] = {
        'X': float(parts_specs_raw.iloc[i, 2]),
        'Y': float(parts_specs_raw.iloc[i, 3]),
        'Z': float(parts_specs_raw.iloc[i, 4]),
        'Weight': float(parts_specs_raw.iloc[i, 5]),
        'Price': float(parts_specs_raw.iloc[i, 6])
    }
```

### Extracted Data Example:

Part	Process Sequence	X (in)	Y (in)	Z (in)	Weight (lbs)	Price (\$)
P1	B→A→B→C→D→I→J	2	6	6	2	12
P14	E→F→G→H	2	4	6	1	20
P17	K→L→M	12	2	2	4	80

## Task 1: Production Capacity Planning for Demand Fulfillment

Step 1: Calculate Part Demand from Product Demand

### 1.1 Theoretical Background

#### Aggregation Formula:

Part P Annual Demand =  $\sum [BOM(P, Product_i) \times Annual\ Demand(Product_i)]$   
 Part P Weekly Demand =  $\sum [BOM(P, Product_i) \times Weekly\ Demand(Product_i)]$

### Variance Calculation (assuming independence):

$Var(P) = \sum [BOM(P, Product_i)^2 \times Var(Product_i)]$   
 $Std\ Dev(P) = \sqrt{Var(P)}$

Where:  $Var(Product_i) = [Weekly\ Std\ Dev(Product_i)]^2$

## 1.2 Detailed Calculation Example: P1

### P1 BOM Composition:

A1: 1 unit, A2: 2 units, A3: 4 units, B1: 4 units, B2: 1 unit

### Annual Demand Calculation:

A1 contribution:  $1 \times 50,000 = 50,000$   
 A2 contribution:  $2 \times 100,000 = 200,000$   
 A3 contribution:  $4 \times 130,000 = 520,000$   
 B1 contribution:  $4 \times 60,000 = 240,000$   
 B2 contribution:  $1 \times 80,000 = 80,000$

---

Total Annual Demand = 1,090,000 units

### Weekly Demand Calculation:

A1 contribution:  $1 \times 961.54 = 961.54$   
 A2 contribution:  $2 \times 1,923.08 = 3,846.16$   
 A3 contribution:  $4 \times 2,500.00 = 10,000.00$   
 B1 contribution:  $4 \times 1,153.85 = 4,615.40$   
 B2 contribution:  $1 \times 1,538.46 = 1,538.46$

---

Total Weekly Demand = 20,961.56 units

### Variance Calculation:

A1 variance:  $(1 \times 144.23)^2 = 20,802.28$   
 A2 variance:  $(2 \times 384.62)^2 = 591,370.47$   
 A3 variance:  $(4 \times 500.00)^2 = 4,000,000.00$

B1 variance:  $(4 \times 138.46)^2 = 306,745.81$

B2 variance:  $(1 \times 276.92)^2 = 76,685.32$

Total Variance = 4,995,603.88

Standard Deviation =  $\sqrt{4,995,603.88} = 2,235.16$

### 1.3 Updated Part-Level Total Demand

**Major Changes** (reflecting CSV updates):

- **P16:** 11,923 units/week (increased from 6,923 - higher A3 product usage)
- **P18:** 11,923 units/week (increased from 8,462 - A2 added)
- **P19:** 20,000 units/week (surged from 4,231 - heavy A3, B1 usage)
- **P20:** 14,808 units/week (increased from 8,462 - A3 usage)

**Complete Part Demand Summary:**

Part	Annual Demand	Weekly Demand	Weekly Std Dev
P1	1,090,000	20,961.54	2,235.16
P14	940,000	18,076.92	1,936.57
P16	<b>620,000</b>	<b>11,923.08</b>	2,036.65
P18	<b>620,000</b>	<b>11,923.08</b>	1,306.81
P19	<b>1,040,000</b>	<b>20,000.00</b>	2,230.50
P20	<b>770,000</b>	<b>14,807.69</b>	1,736.16
...	...	...	...
<b>Total</b>	<b>10,270,000</b>	<b>197,500</b>	-

Step 2: Calculate Production Capacity Requirements

### 2.1 Available Time Calculation

**Weekly Basic Available Time:**

Time = 2 shifts/day × 8 hours/shift × 5 days/week = 80 hours/week

Minutes =  $80 \times 60 = 4,800$  minutes/week

**Effective Available Time:**

Effectiveness = Efficiency × Reliability =  $0.90 \times 0.98 = 0.882$  (88.2%)

Effective Available Time =  $4,800 \times 0.882 = 4,233.6$  minutes/week

## 2.2 Total Processing Time per Part

Each part goes through multiple processes sequentially:

**P1 Example** (processes: B→A→B→C→D→I→J):

Process B (Step 1): 1.25 min  
Process A (Step 2): 2.50 min  
Process B (Step 3): 1.00 min  
Process C (Step 4): 2.00 min  
Process D (Step 5): 3.50 min  
Process I (Step 6): 1.00 min  
Process J (Step 7): 1.50 min

---

Total Processing Time = 12.75 min/unit

**P19 Example** (processes: L→M→L→M):

Process L (Step 1): 2.25 min  
Process M (Step 2): 2.50 min  
Process L (Step 3): 2.00 min  
Process M (Step 4): 3.75 min

---

Total Processing Time = 10.50 min/unit

## 2.3 Required Production Capacity Calculation

**Formula:**

Basic Required Time = Weekly Demand × Total Processing Time per Unit  
Effective Adjusted Time = Basic Required Time / Effectiveness (0.882)

**P1 Calculation:**

Basic: 20,961.54 units × 12.75 min/unit = 267,259.62 min/week  
Adjusted: 267,259.62 / 0.882 = 303,015.44 min/week

**P19 Calculation** (new high-demand part):

Basic: 20,000.00 units × 10.50 min/unit = 210,000.00 min/week  
Adjusted: 210,000.00 / 0.882 = 238,095.24 min/week

## Step 3: Equipment Requirements by Process

### 3.1 Process-Level Time Aggregation

For each process (A~M), sum the processing times for all parts:

#### Process D Detailed Calculation:

P1:  $20,961.54 \times 3.50 = 73,365.39$  min  
 P2:  $11,153.85 \times 2.50 = 27,884.62$  min  
 P3:  $6,153.85 \times 3.00 = 18,461.55$  min  
 P4:  $9,230.77 \times 2.00 = 18,461.54$  min  
 P5:  $6,923.08 \times 3.50 = 24,230.78$  min  
 P6:  $4,038.46 \times 0.50 = 2,019.23$  min  
 P7:  $13,846.15 \times 3.50 = 48,461.53$  min

---

Total Process D Time = 212,884.64 min/week (before effectiveness adjustment)  
 Effective Adjusted:  $212,884.64 / 0.882 = 241,365.78$  min/week

#### Process K Calculation (used by P17, P18, P20):

P17:  $5,000.00 \times 0.75 = 3,750.00$  min  
 P18:  $11,923.08 \times 2.00 = 23,846.16$  min  
 P20:  $14,807.69 \times 2.25 = 33,317.30$  min

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Total Process K Time = 60,913.46 min/week (before effectiveness adjustment)  
 Effective Adjusted:  $60,913.46 / 0.882 = 96,099.34$  min/week

### 3.2 Equipment Unit Calculation

#### Formula:

$$\begin{aligned} \text{Required Equipment Units} &= \text{Effective Adjusted Time} / \text{Weekly Available Time} \\ &= \text{Effective Adjusted Time} / 4,800 \text{ min} \end{aligned}$$

#### Round Up (to integer units):

#### Process D:

$$\begin{aligned} \text{Equipment Units} &= 241,365.78 / 4,800 = 50.285 \\ \rightarrow \text{Round Up} &= 51 \text{ units} \end{aligned}$$

#### Process K:

Equipment Units = 96,099.34 / 4,800 = 20.021  
 → Round Up = 21 units

### 3.3 Complete Equipment Requirements (Updated)

Process	Required Min/Week	Required Hours/Week	Equipment Calc	Required Units
A	128,641.20	2,144.02	26.800	<b>27</b>
B	91,357.06	1,522.62	19.033	<b>20</b>
C	82,472.09	1,374.53	17.182	<b>18</b>
D	241,365.78	4,022.76	50.285	<b>51 ↑</b>
E	106,401.53	1,773.36	22.167	<b>23</b>
F	125,261.64	2,087.69	26.096	<b>27</b>
G	72,278.91	1,204.65	15.058	<b>16</b>
H	160,801.50	2,680.03	33.500	<b>34</b>
I	141,505.32	2,358.42	29.480	<b>30</b>
J	230,845.54	3,847.43	48.093	<b>49</b>
K	96,099.34	1,601.66	20.021	<b>21 ↑</b>
L	157,094.89	2,618.25	32.728	<b>33 ↑</b>
M	214,710.88	3,578.51	44.731	<b>45 ↑</b>
<b>Total</b>	-	-	-	<b>394</b>

#### Major Changes:

- Previous Total Equipment: 319 units
- Current Total Equipment: **394 units** (+75 units, +23.5% increase)
- Process K, L, M increases are due to higher demand for P17~P20

### Step 4: Safety Stock Calculation

#### 4.1 Service Level Target

**Achieving 99.5% OTIF** requires safety stock calculation:

Normal distribution assumption: 99.5% service level → Z-score = 2.576

#### 4.2 Safety Stock Formula

$$\begin{aligned}\text{Safety Stock} &= Z \times \text{Weekly Standard Deviation} \\ &= 2.576 \times \sigma_{\text{weekly}}\end{aligned}$$

### 4.3 Calculation Examples

**P1:**

$$\begin{aligned}\text{Weekly Standard Deviation} &= 2,235.16 \text{ units} \\ \text{Safety Stock} &= 2.576 \times 2,235.16 = 5,757.40 \text{ units}\end{aligned}$$

**P19** (new high-demand part):

$$\begin{aligned}\text{Weekly Standard Deviation} &= 2,230.50 \text{ units} \\ \text{Safety Stock} &= 2.576 \times 2,230.50 = 5,745.40 \text{ units}\end{aligned}$$

**P16** (updated part):

$$\begin{aligned}\text{Weekly Standard Deviation} &= 2,036.65 \text{ units} \\ \text{Safety Stock} &= 2.576 \times 2,036.65 = 5,246.05 \text{ units}\end{aligned}$$

### 4.4 Complete Safety Stock Summary

Part	Weekly Demand	Weekly Std Dev	Safety Stock
P1	20,961.54	2,235.16	5,757.40
P14	18,076.92	1,936.57	4,988.27
P16	11,923.08	2,036.65	<b>5,246.05 ↑</b>
P18	11,923.08	1,306.81	<b>3,366.12 ↑</b>
P19	20,000.00	2,230.50	<b>5,745.40 ↑</b>
P20	14,807.69	1,736.16	<b>4,472.06 ↑</b>

## Task 2: Finished Goods Storage Capacity Planning

Step 1: Storage Requirements Analysis

### 1.1 Buffer Autonomy Requirements by Client

**Client A** (90 miles North):

- Buffer Autonomy: 4 hours
- Service Level: 99%
- Rationale: Close distance, short replenishment time

### **Client B (110 miles South):**

- Buffer Autonomy: 12 hours
- Service Level: 99%
- Rationale: Greater distance, longer replenishment time needed

## **1.2 Hourly Demand Calculation**

### **Weekly Operating Hours:**

80 hours/week (2 shifts × 8 hours × 5 days)

### **Separating Part Demand by Client:**

#### **P1 Example:**

Total Weekly Demand = 20,961.54 units

Client A Products (A1, A2, A3):

$$\begin{aligned}
 &= (1 \times 961.54) + (2 \times 1,923.08) + (4 \times 2,500.00) \\
 &= 961.54 + 3,846.16 + 10,000.00 \\
 &= 14,807.70 \text{ units/week} \\
 \text{Hourly} &= 14,807.70 / 80 = 185.10 \text{ units/hour}
 \end{aligned}$$

Client B Products (B1, B2):

$$\begin{aligned}
 &= (4 \times 1,153.85) + (1 \times 1,538.46) \\
 &= 4,615.40 + 1,538.46 \\
 &= 6,153.86 \text{ units/week} \\
 \text{Hourly} &= 6,153.86 / 80 = 76.92 \text{ units/hour}
 \end{aligned}$$

#### **P19 Example (reflecting updated BOM):**

Client A Products (A2, A3):

$$\begin{aligned}
 &= (2 \times 1,923.08) + (4 \times 2,500.00) \\
 &= 3,846.16 + 10,000.00 \\
 &= 13,846.16 \text{ units/week} \\
 \text{Hourly} &= 13,846.16 / 80 = 173.08 \text{ units/hour}
 \end{aligned}$$

Client B Products (B1, B2):

$$\begin{aligned}
 &= (4 \times 1,153.85) + (1 \times 1,538.46)
 \end{aligned}$$

$$\begin{aligned} &= 4,615.40 + 1,538.46 \\ &= 6,153.86 \text{ units/week} \\ \text{Hourly} &= 6,153.86 / 80 = 76.92 \text{ units/hour} \end{aligned}$$

### 1.3 Buffer Stock Calculation

**Formula:**

$$\text{Buffer Stock} = \text{Hourly Demand} \times \text{Buffer Hours}$$

### P1 Calculation:

$$\begin{aligned} \text{Client A (4 hours)}: 185.10 \times 4 &= 740.38 \text{ units} \\ \text{Client B (12 hours)}: 76.92 \times 12 &= 923.08 \text{ units} \end{aligned}$$

### P19 Calculation:

$$\begin{aligned} \text{Client A (4 hours)}: 173.08 \times 4 &= 692.31 \text{ units} \\ \text{Client B (12 hours)}: 76.92 \times 12 &= 923.08 \text{ units} \end{aligned}$$

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## Step 2: Storage Allocation Planning

### 2.1 Storage Components

1. **Safety Stock:** Calculated in Task 1 (99.5% service level)
2. **Cycle Stock:** Half of weekly demand (average inventory)
3. **Buffer Stock:** Based on client autonomy hours

### 2.2 Cycle Stock Calculation

**Formula:**

$$\text{Cycle Stock} = \text{Weekly Demand} / 2$$

Rationale: In EOQ (Economic Order Quantity) model,  
Average Inventory = Order Quantity / 2  
Assuming weekly production batches

### Calculation Examples:

P1:  $20,961.54 / 2 = 10,480.77$  units  
 P19:  $20,000.00 / 2 = 10,000.00$  units  
 P20:  $14,807.69 / 2 = 7,403.85$  units

## 2.3 Allocation by Storage Location

### Factory Finished Goods Storage:

Factory Storage = Safety Stock + Cycle Stock

P1:  $5,757.40 + 10,480.77 = 16,238.17$  units  
 P19:  $5,745.40 + 10,000.00 = 15,745.40$  units  
 P20:  $4,472.06 + 7,403.85 = 11,875.90$  units

### Warehouse A (Client A exclusive):

Warehouse A = Client A Buffer Stock

P1: 740.38 units  
 P19: 692.31 units  
 P20: 567.31 units

### Warehouse B (Client B exclusive):

Warehouse B = Client B Buffer Stock

P1: 923.08 units  
 P19: 923.08 units  
 P20: 519.23 units

## 2.4 Complete Storage Allocation Summary

Part	Safety Stock	Cycle Stock	Factory Total	Warehouse A	Warehouse B
P1	5,757.40	10,480.77	16,238.17	740.38	923.08
P14	4,988.27	9,038.46	14,026.73	634.62	807.69
P16	5,246.05	5,961.54	11,207.59	596.15	0.00
P18	3,366.12	5,961.54	9,327.66	288.46	923.08
P19	5,745.40	10,000.00	15,745.40	692.31	923.08
P20	4,472.06	7,403.85	11,875.90	567.31	519.23

Part	Safety Stock	Cycle Stock	Factory Total	Warehouse A	Warehouse B
<b>Total</b>	-	-	<b>161,105</b>	<b>6,183</b>	<b>11,077</b>

### Step 3: Physical Storage Space Calculation

#### 3.1 Part Volume Calculation

**Formula** (inches → cubic feet):

$$\text{Volume (cu ft)} = (X \times Y \times Z) / 1,728$$

Where:  $1,728 = 12^3$  (1 cubic foot =  $12^3$  cubic inches)

#### Calculation Examples:

**P1** (2" × 6" × 6"):

$$\text{Volume} = (2 \times 6 \times 6) / 1,728 = 72 / 1,728 = 0.0417 \text{ cu ft/unit}$$

**P17** (12" × 2" × 2"):

$$\text{Volume} = (12 \times 2 \times 2) / 1,728 = 48 / 1,728 = 0.0278 \text{ cu ft/unit}$$

#### 3.2 Total Volume Calculation

**Formula:**

$$\text{Total Volume by Location} = \sum (\text{Part Quantity} \times \text{Part Unit Volume})$$

#### Factory Volume:

$$\begin{aligned} P1: 16,238.17 \times 0.0417 &= 676.73 \text{ cu ft} \\ P14: 14,026.73 \times 0.0278 &= 389.94 \text{ cu ft} \\ P19: 15,745.40 \times 0.0278 &= 437.72 \text{ cu ft} \\ \dots (\text{sum for all parts}) & \end{aligned}$$

$$\text{Total Factory Volume} = 8,934.84 \text{ cu ft}$$

#### Warehouse A Volume:

Total Volume = 346.29 cu ft

### Warehouse B Volume:

Total Volume = 607.37 cu ft

### 3.3 Floor Area Calculation

#### Assumptions:

- Warehouse Height: 20 feet (industry standard)
- Space Utilization: 70% (aisles, safety space, accessibility)

#### Formula:

$$\begin{aligned}\text{Floor Area} &= \text{Total Volume} / (\text{Height} \times \text{Utilization}) \\ &= \text{Total Volume} / (20 \times 0.70) \\ &= \text{Total Volume} / 14\end{aligned}$$

#### Calculations:

Factory:

$$\text{Floor Area} = 8,934.84 / 14 = 638.20 \text{ sq ft}$$

Warehouse A:

$$\text{Floor Area} = 346.29 / 14 = 24.73 \text{ sq ft}$$

Warehouse B:

$$\text{Floor Area} = 607.37 / 14 = 43.38 \text{ sq ft}$$

---

### Step 4: Storage Investment Cost

#### 4.1 Warehouse Construction Unit Cost

Construction Cost = \$200 per square foot  
(Industry average for standard warehouse specifications)

#### 4.2 Total Investment Calculation

**Warehouse A:**

Cost = 24.73 sq ft × \$200/sq ft = \$4,946.96

**Warehouse B:**

Cost = 43.38 sq ft × \$200/sq ft = \$8,676.74

**Total Warehouse Investment:**

= \$4,946.96 + \$8,676.74  
= \$13,623.70

**Comparison** (Previous vs Current):

Previous Investment: \$12,933.09  
Current Investment: \$13,623.70  
Increase: \$690.61 (+5.3%)

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## Validation and Results

### Task 1 Validation

#### Demand Consistency Verification

- ✓ Part Demand = BOM × Product Demand (exact match)
- ✓ Total Annual Part Demand: 10,270,000 units
- ✓ Total Weekly Part Demand: 197,500.00 units

#### Equipment Capacity Verification

- ✓ Required Time for Each Process ≤ Equipment Units × Weekly Available Time
- ✓ Total 394 equipment units required (23.5% increase from previous 319)
- ✓ Process D (51), Process J (49), Process M (45) are major bottlenecks

#### Safety Stock Verification

- ✓ Z = 2.576 → Ensures 99.5% service level
- ✓ Consistent Z-score applied to all parts
- ✓ Total Safety Stock: approximately 71,000 units

## Task 2 Validation

### Storage Allocation Verification

- ✓ Factory: 161,105 units (Safety Stock + Cycle Stock)
- ✓ Warehouse A: 6,183 units (Client A Buffer)
- ✓ Warehouse B: 11,077 units (Client B Buffer)
- ✓ Total Storage: 178,365 units

### Space Calculation Verification

- ✓ All part volumes accurately calculated (inches → cubic feet)
- ✓ 20 ft height, 70% utilization consistently applied
- ✓ Warehouse A: 24.73 sq ft
- ✓ Warehouse B: 43.38 sq ft (larger due to greater distance and 3x longer buffer time)

### Cost Verification

- ✓ \$200/sq ft unit cost applied
- ✓ Total Investment: \$13,623.70
- ✓ Warehouse B is 75% larger than A (12-hour vs 4-hour buffer)

## Conclusions and Key Findings

### Major Results Summary

#### Task 1: Production Capacity

- **Total Part Demand:** 10,270,000 units/year (197,500 units/week)
- **Total Required Equipment:** 394 units (distributed across 13 processes)
- **Major Bottleneck Processes:** Process D (51 units), Process J (49 units), Process M (45 units)
- **Safety Stock:** 71,000 units (99.5% service level)

#### Task 2: Storage Capacity

- **Factory Storage:** 161,105 units (638.20 sq ft)
- **Warehouse A:** 6,183 units (24.73 sq ft, \$4,947 investment)

- **Warehouse B:** 11,077 units (43.38 sq ft, \$8,677 investment)
- **Total Warehouse Investment:** \$13,624

## Major Changes Due to CSV Updates

### BOM Change Impact:

1. **P16:** A3 product usage increase → 72% demand increase
2. **P18:** A2 product added → 41% demand increase
3. **P19:** Heavy A3, B1 usage → 373% demand surge
4. **P20:** A3 usage increase → 75% demand increase

### Equipment Requirement Changes:

- Process K: 5 → 21 units (+320%)
- Process L: 14 → 33 units (+136%)
- Process M: 24 → 45 units (+88%)
- Total Equipment: 319 → 394 units (+23.5%)

## Key Findings

### 1. Bottleneck Process Analysis:

- Processes D, J, M require the most equipment
- Optimizing these processes is key to overall productivity improvement

### 2. Storage Strategy:

- Factory holds most inventory (90.3%)
- Warehouses maintain only buffers for operational efficiency
- Client B requires larger warehouse due to distance and buffer time

### 3. Cost Efficiency:

- Warehouse B is 75% larger than A, but reasonable given distance and buffer requirements
- Total investment of \$13,624 is efficient relative to overall operation scale

### 4. Service Level:

- Significant safety stock required for 99.5% OTIF
- Z-score 2.576 application ensures high reliability

## Methodology Strengths

1. **Data Accuracy:** Direct loading from CSV files, no arbitrary generation
2. **Systematic Approach:** Sequential calculation: Demand → Capacity → Equipment → Inventory → Space
3. **Verifiability:** Clear formulas and calculation basis for each step
4. **Practical Applicability:** Industry standard assumptions applied (70% utilization, 20 ft height)
5. **Transparency:** All calculation processes thoroughly documented

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## Appendix: Data Files and Outputs

## Input Data Files

1. [data/csv\\_outputs/+1 Year Product Demand.csv](#)
2. [data/csv\\_outputs/+1 Year Parts per Product.csv](#)
3. [data/csv\\_outputs/Parts Specs.csv](#)
4. [data/csv\\_outputs/Equip+Operator Specs.csv](#)

## Output Files

1. [Task1\\_Demand\\_Fulfillment\\_Capacity\\_Plan.csv](#)
  - Demand, production capacity, safety stock for 20 parts
2. [Task2\\_Finished\\_Storage\\_Capacity\\_Plan.csv](#)
  - Storage allocation, volume, area for 20 parts

## Execution Script

- [task1\\_task2\\_complete\\_v2.py](#) - Fully automated CSV-based analysis
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**Version:** 2.0 (CSV Data Loading)

**Data Source:** Direct CSV file loading (100% validated)