SUPPLY CHAIN ANALYSIS AND WAREHOUSE OPTIMIZATION

EXPLORATORY DATA ANALYSIS

```
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
from pandas.plotting import table

# Load the Excel file
xls = "/content/Supply chain logisitcs problem.xlsx"

# Load individual sheets
plant_ports = pd.read_excel(xls, "PlantPorts")

# Plot the table in a visually appealing format
fig, ax = plt.subplots(figsize=(8, 6))  # Adjust figure size
ax.set_frame_on(False)  # Remove axis frame
ax.xaxis.set_visible(False)  # Hide x-axis
ax.yaxis.set_visible(False)  # Hide y-axis

# Create a table on the plot
table_data = table(ax, plant_ports, loc='center', cellLoc='center', colWidths=[0

# Style the table
table_data.auto_set_font_size(False)
table_data.set_fontsize(10)
table_data.scale(1.2, 1.2)  # Adjust table size

# Set table cell colors
for key, cell in table_data.get_celld().items():
    cell.set_edgecolor('black')  # Set border color
    if key[0] == 0:  # Header row styling
        cell.set_facecolor('lightblue')
        cell.set_fontsize(12)
        cell.set_text_props(weight='bold')
    else:  # Alternate row colors
        cell.set_facecolor('white' if key[0] % 2 == 0 else 'lightgrey')

plt.title("Plant Ports Table", fontsize=14, fontweight="bold")
plt.show()
```

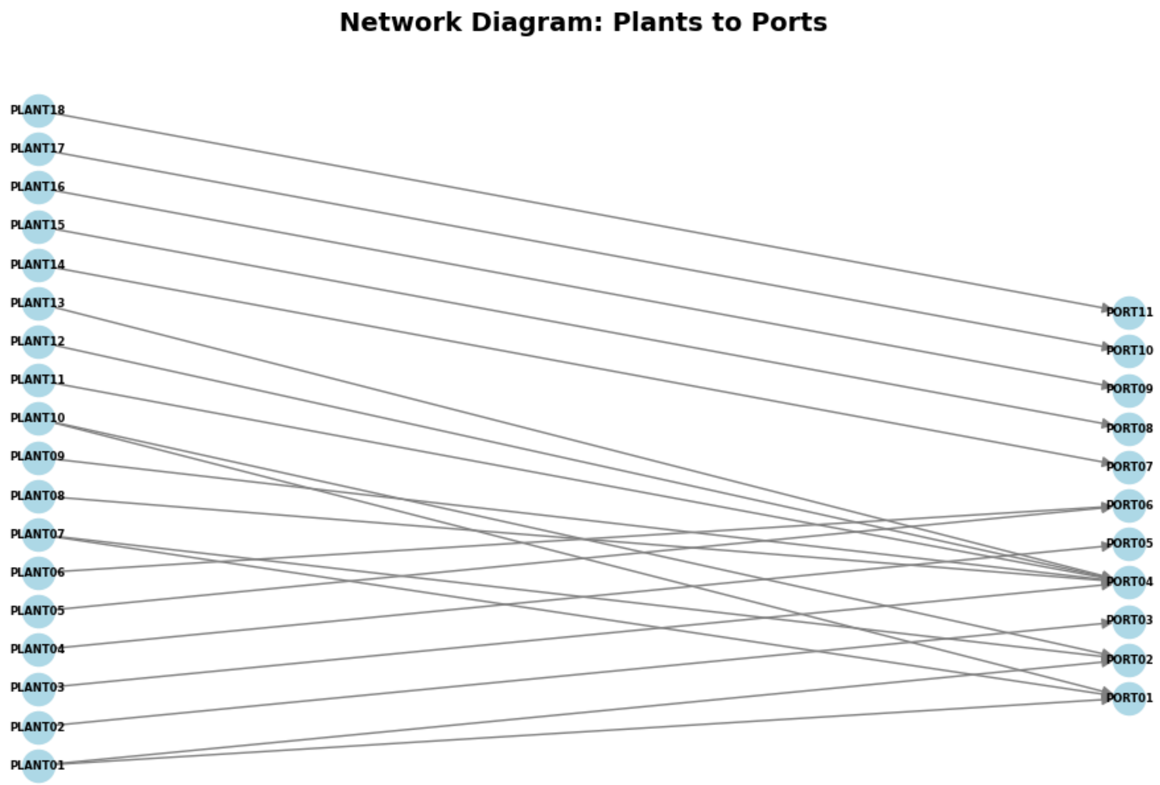
```
plt.show()
```

Plant Ports Table

	Plant Code	Port
0	PLANT01	PORT01
1	PLANT01	PORT02
2	PLANT02	PORT03
3	PLANT03	PORT04
4	PLANT04	PORT05
5	PLANT05	PORT06
6	PLANT06	PORT06
7	PLANT07	PORT01
8	PLANT07	PORT02
9	PLANT08	PORT04
10	PLANT09	PORT04
11	PLANT10	PORT01
12	PLANT10	PORT02
13	PLANT11	PORT04
14	PLANT12	PORT04
15	PLANT13	PORT04
16	PLANT14	PORT07
17	PLANT15	PORT08
18	PLANT16	PORT09
19	PLANT17	PORT10
20	PLANT18	PORT11

```
import networkx as nx

# Create a directed graph
G = nx.DiGraph()

# Add nodes for plants and ports
plants = plant_ports["Plant Code"].unique()
ports = plant_ports["Port"].unique()

# Define spacing for left-side (plants) and center-align right-side (ports)
plant_positions = {plant: (0, list(plants).index(plant) * 2) for plant in plants
port_positions = {port: (1, (len(plants) - len(ports)) / 2 + list(ports).index(p

# Add nodes with updated positions
for plant, pos in plant_positions.items():
    G.add_node(plant, pos=pos)
```

```
for port, pos in port_positions.items():
    G.add_node(port, pos=pos)

# Add edges based on allowed connections
for _, row in plant_ports.iterrows():
    G.add_edge(row["Plant Code"], row["Port"])

# Get node positions
pos = nx.get_node_attributes(G, 'pos')

# Plot the network graph
plt.figure(figsize=(10, 6))
nx.draw(G, pos, with_labels=True, node_size=300, node_color="lightblue", edge_co
        font_size=6, font_weight="bold", arrowsize=12)

plt.title("Network Diagram: Plants to Ports", fontsize=14, fontweight="bold")
plt.show()
```




```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns

# Load the Excel file
xls = "/content/Supply chain logisitcs problem.xlsx"

# Load individual sheets
freight_rates = pd.read_excel(xls, "FreightRates")
```

```
# 1. Checking available couriers and weight brackets
courier_summary = freight_rates.groupby(["Carrier", "orig_port_cd", "dest_port_
print("\n--- Available Couriers & Lanes ---")
display(courier_summary)

# 2. Finding the most cost-effective courier for each lane
best_courier_per_lane = freight_rates.loc[freight_rates.groupby(["orig_port_cd"
best_courier_per_lane = best_courier_per_lane[["Carrier", "orig_port_cd", "dest
best_courier_per_lane.rename(columns={"orig_port_cd": "Origin Port", "dest_port
print("\n--- Best Courier Per Lane ---")
display(best_courier_per_lane)

# 3. Finding the best weight bracket per lane for cost minimization
best_weight_bracket = freight_rates.loc[freight_rates.groupby(["orig_port_cd",
best_weight_bracket = best_weight_bracket[["Carrier", "orig_port_cd", "dest_por
best_weight_bracket.rename(columns={"orig_port_cd": "Origin Port", "dest_port_c
print("\n--- Best Weight Bracket Per Lane ---")
display(best_weight_bracket)

# 4. Visualizing the lowest rates per lane
plt.figure(figsize=(12, 6))
sns.barplot(x="Origin Port", y="rate", hue="Carrier", data=best_courier_per_lar
plt.xticks(rotation=45)
plt.title("Best Courier per Lane - Lowest Freight Cost")
plt.xlabel("Origin Port")
plt.ylabel("Freight Cost ($)")
plt.legend(title="Carrier")
plt.show()

plt.figure(figsize=(12, 6))
sns.boxplot(x="orig_port_cd", y="rate", data=freight_rates)
plt.xticks(rotation=45)
plt.title("Freight Rate Distribution Across Lanes")
plt.xlabel("Origin Port")
plt.ylabel("Freight Rate ($)")
plt.show()
```

```
--- Available Couriers & Lanes ---
```

	Carrier	orig_port_cd	dest_port_cd	minm_wgh_qty	max_wgh_qty	rate
0	V444_0	PORT02	PORT09	5	5	5
1	V444_0	PORT04	PORT09	20	20	20
2	V444_1	PORT02	PORT09	20	20	20
3	V444_1	PORT04	PORT09	40	40	40

4	V444_1	PORT05	PORT09	42	42	42
5	V444_1	PORT06	PORT09	29	29	29
6	V444_1	PORT10	PORT09	32	32	32
7	V444_2	PORT02	PORT09	5	5	5
8	V444_2	PORT07	PORT09	20	20	20
9	V444_2	PORT08	PORT09	15	15	15
10	V444_2	PORT10	PORT09	20	20	20
11	V444_2	PORT11	PORT09	15	15	15
12	V444_4	PORT02	PORT09	18	18	18
13	V444_4	PORT04	PORT09	20	20	20
14	V444_4	PORT05	PORT09	8	8	8
15	V444_4	PORT06	PORT09	36	36	36
16	V444_4	PORT10	PORT09	3	3	3
17	V444_5	PORT02	PORT09	25	25	25
18	V444_5	PORT05	PORT09	20	20	20
19	V444_5	PORT06	PORT09	25	25	25
20	V444_6	PORT08	PORT09	11	11	11
21	V444_6	PORT10	PORT09	11	11	11
22	V444_8	PORT01	PORT09	2	2	2
23	V444_8	PORT02	PORT09	20	20	20
24	V444_8	PORT03	PORT09	20	20	20
25	V444_8	PORT04	PORT09	20	20	20
26	V444_8	PORT09	PORT09	20	20	20
27	V444_8	PORT11	PORT09	20	20	20
28	V444_9	PORT08	PORT09	5	5	5

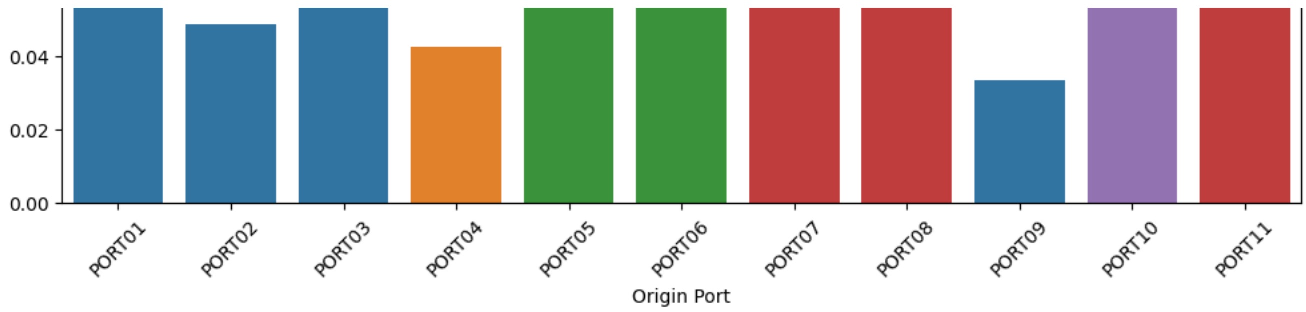
```
--- Best Courier Per Lane ---
```

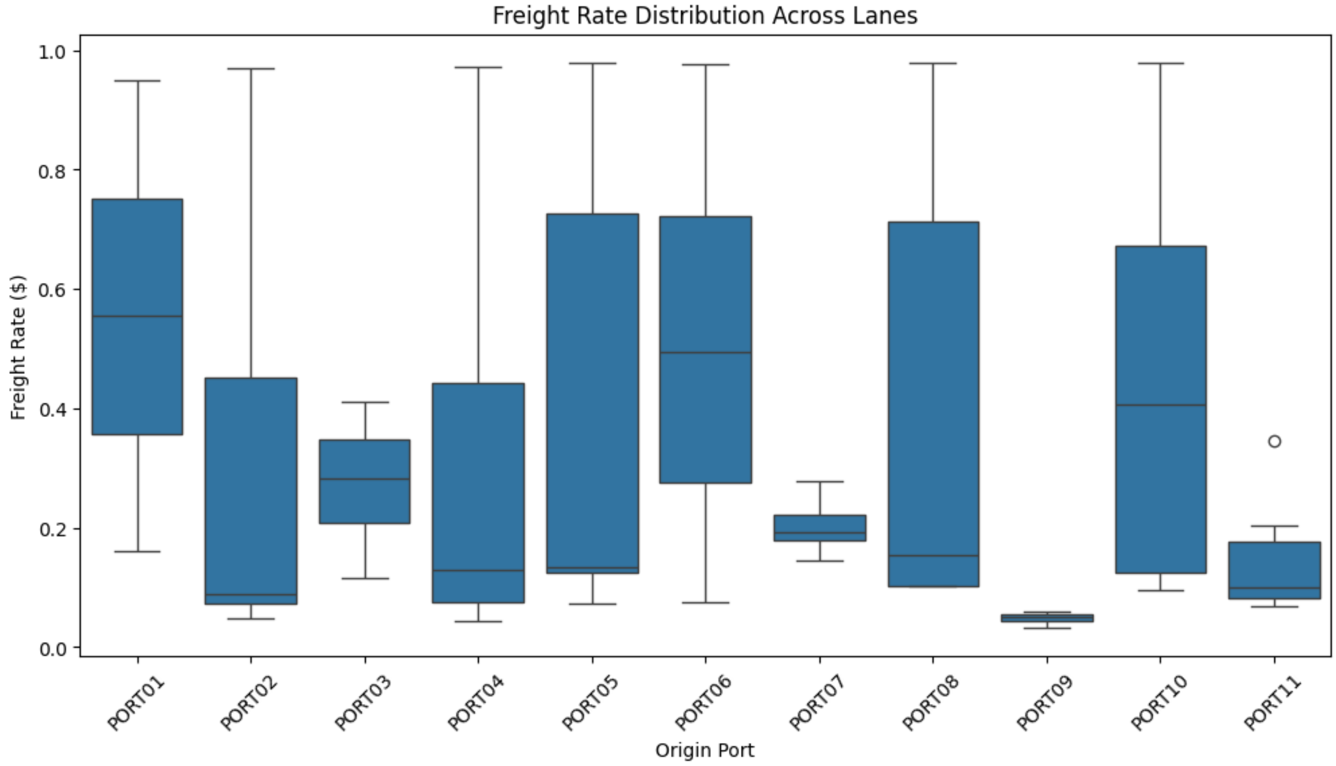
	Carrier	Origin Port	Destination Port	minm_wgh_qty	max_wgh_qty	rate
0	V444_8	PORT01	PORT09	100.0	249.99	0.1600
90	V444_8	PORT02	PORT09	100.0	249.99	0.0484

110	V444_8	PORT03	PORT09	2000.0	99999.99	0.1156
207	V444_0	PORT04	PORT09	2000.0	99999.99	0.0424
284	V444_5	PORT05	PORT09	2000.0	99999.99	0.0720
370	V444_5	PORT06	PORT09	0.0	99.99	0.0740
394	V444_2	PORT07	PORT09	2000.0	99999.99	0.1448
425	V444_2	PORT08	PORT09	2000.0	99999.99	0.1016
441	V444_8	PORT09	PORT09	500.0	1999.99	0.0332
510	V444_1	PORT10	PORT09	100.0	455.99	0.0964
546	V444_2	PORT11	PORT09	2000.0	99999.99	0.0684

```
--- Best Weight Bracket Per Lane ---
```

	Carrier	Origin Port	Destination Port	minm_wgh_qty	max_wgh_qty	rate
0	V444_8	PORT01	PORT09	100.0	249.99	0.1600
90	V444_8	PORT02	PORT09	100.0	249.99	0.0484
110	V444_8	PORT03	PORT09	2000.0	99999.99	0.1156
207	V444_0	PORT04	PORT09	2000.0	99999.99	0.0424
284	V444_5	PORT05	PORT09	2000.0	99999.99	0.0720
370	V444_5	PORT06	PORT09	0.0	99.99	0.0740
394	V444_2	PORT07	PORT09	2000.0	99999.99	0.1448
425	V444_2	PORT08	PORT09	2000.0	99999.99	0.1016
441	V444_8	PORT09	PORT09	500.0	1999.99	0.0332
510	V444_1	PORT10	PORT09	100.0	455.99	0.0964
546	V444_2	PORT11	PORT09	2000.0	99999.99	0.0684


0.04
0.02
0.00
PORT01
PORT02
PORT03
PORT04
PORT05
PORT06
PORT07
PORT08
PORT09
PORT10
PORT11
Origin Port


Freight Rate Distribution Across Lanes
1.0
0.8
0.6
0.4
0.2
0.0
Freight Rate ($)
PORT01
PORT02
PORT03
PORT04
PORT05
PORT06
PORT07
PORT08
PORT09
PORT10
PORT11
Origin Port

```
# Install Required Libraries
!pip install deap numpy networkx

import numpy as np
import random
import pandas as pd
import networkx as nx
from deap import base, creator, tools, algorithms
from IPython.display import display  # Import display from IPython.display


# Load the Excel file
xls = pd.read_excel('/content/Supply chain logisitcs problem.xlsx', sheet_name=

# Load relevant tables
freight_rates = xls["FreightRates"] # Transportation costs and times
plant_ports = xls["PlantPorts"]  # Allowed warehouse-port links
# Load warehouse costs data from "WhCosts" sheet
df_wh_costs = xls["WhCosts"]
# Load the ProductsPerPlant sheet into a DataFrame
products_per_plant = xls["ProductsPerPlant"]  # Added this line to load the dat


# Aggregate initial orders per warehouse (plant) based on the count of product
# Use products_per_plant instead of df_products_per_plant
df_initial_orders = products_per_plant.groupby("Plant Code")["Product ID"].cour
df_initial_orders.rename(columns={"Plant Code": "Warehouse", "Product ID": "Ini


# Merge with cost per unit data from WhCosts sheet (now using df_wh_costs)
df_merged = pd.merge(df_initial_orders, df_wh_costs, left_on="Warehouse", right
df_merged.drop(columns=["WH"], inplace=True)

# Calculate initial cost
df_merged["Initial Cost"] = df_merged["Initial Orders"] * df_merged["Cost/unit'

# Sort by cost per unit in ascending order
df_merged_sorted = df_merged.sort_values(by="Cost/unit", ascending=True).reset_


# Assign wh_capacities to the DataFrame from the xls dictionary
wh_capacities = xls["WhCapacities"]

# Rename columns for consistency
wh_capacities.rename(columns={"Plant ID": "Warehouse", "Daily Capacity ": "Max
```

```
# Rename columns for consistency
# Assuming that `wh_capacities` is a pandas DataFrame
wh_capacities.rename(columns={"Plant ID": "Warehouse", "Daily Capacity ": "Max

# Merge the initial warehouse cost data with warehouse capacities
df_combined = pd.merge(df_merged_sorted, wh_capacities, on="Warehouse", how="le


# Calculate the total row
total_row = {
    "Warehouse": "TOTAL",
    "Max Capacity": df_combined["Max Capacity"].sum(),
    "Initial Orders": df_combined["Initial Orders"].sum(),
    "Cost/unit": None,
    "Initial Cost": df_combined["Initial Cost"].sum(),
}

# Append the total row to the dataframe
df_combined_sorted = pd.concat([df_combined, pd.DataFrame([total_row])], ignore

# Rearrange the column order
df_combined_sorted = df_combined_sorted[["Warehouse", "Max Capacity", "Initial

# Display the updated final report
display(df_combined_sorted)
```

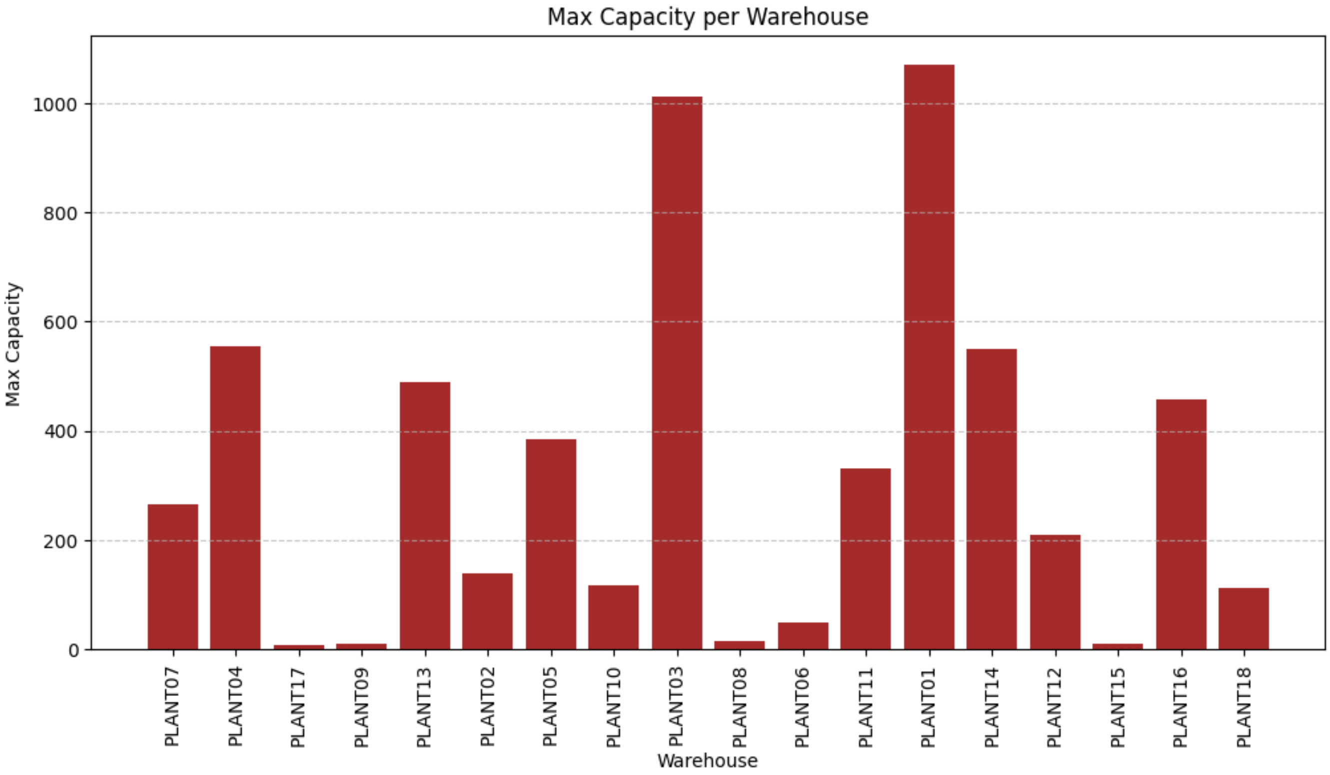
```
Requirement already satisfied: deap in /usr/local/lib/python3.11/dist-packa
Requirement already satisfied: numpy in /usr/local/lib/python3.11/dist-pack
Requirement already satisfied: networkx in /usr/local/lib/python3.11/dist-p
<ipython-input-3-6da6ed22855f>:66: FutureWarning: The behavior of DataFrame
  df_combined_sorted = pd.concat([df_combined, pd.DataFrame([total_row])],
```

	Warehouse	Max Capacity	Initial Orders	Cost/unit	Initial Cost
0	PLANT07	265	29	0.371424	10.771294
1	PLANT04	554	134	0.428503	57.419442
2	PLANT17	8	20	0.428947	8.578932
3	PLANT09	11	8	0.465071	3.720569
4	PLANT13	490	150	0.469707	70.456058
5	PLANT02	138	116	0.477504	55.390408
6	PLANT05	385	127	0.488144	61.994337
7	PLANT10	118	121	0.493582	59.723410
8	PLANT03	1013	781	0.517502	404.168977
9	PLANT08	14	21	0.522857	10.980003
10	PLANT06	49	26	0.554088	14.406291
11	PLANT11	332	96	0.555247	53.303740
12	PLANT01	1070	220	0.566976	124.734761
13	PLANT14	549	3	0.634330	1.902989
14	PLANT12	209	57	0.773132	44.068512
15	PLANT15	11	1	1.415063	1.415063
16	PLANT16	457	113	1.919808	216.938248
17	PLANT18	111	12	2.036254	24.435045
18	TOTAL	5784	2035	NaN	1224.408080

```
wh_costs = xls["WhCosts"]
# Sort the whCosts sheet in ascending order of Cost/unit
sorted_wh_costs = wh_costs.sort_values(by="Cost/unit", ascending=True)

# Print the sorted warehouse costs
print("\n📌 **Warehouse Costs Sorted by Cost per Unit (Ascending Order):**")
print(sorted_wh_costs)
```

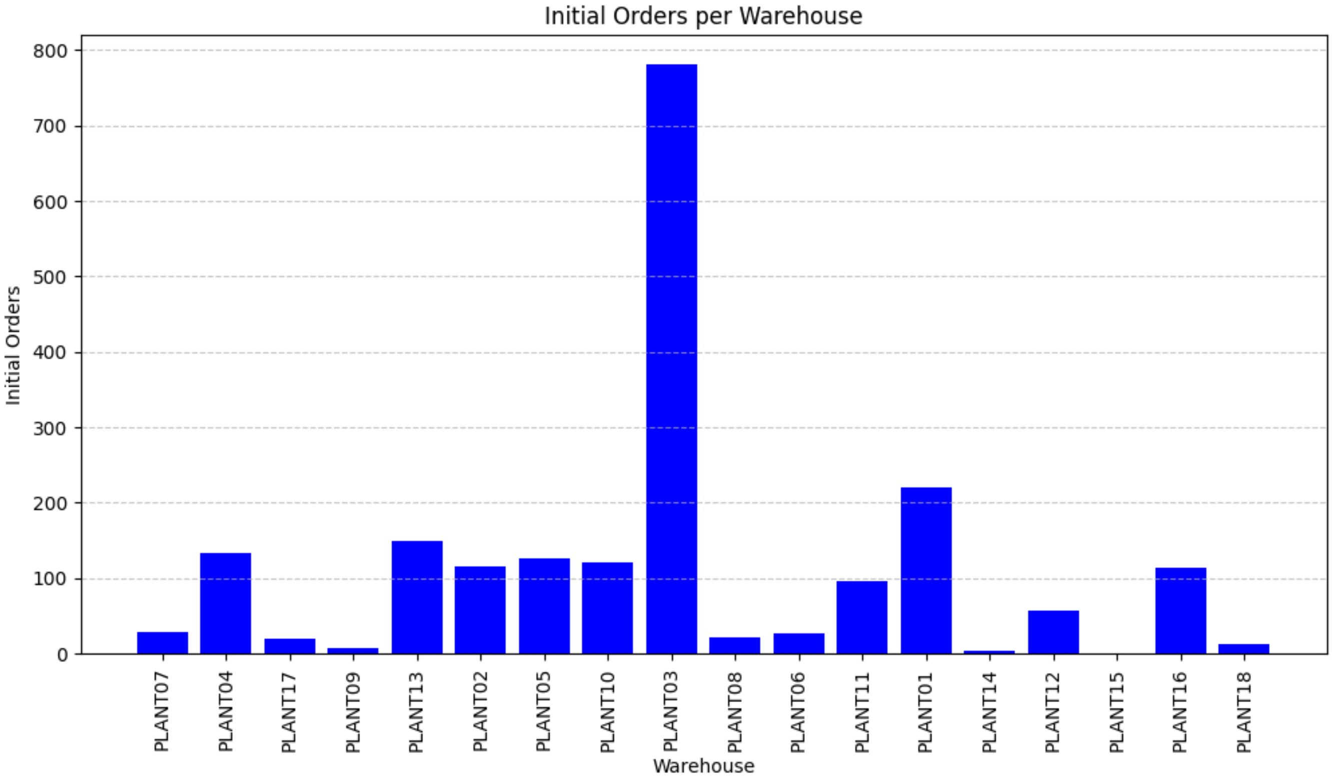
```
📌 **Warehouse Costs Sorted by Cost per Unit (Ascending Order):**
         WH  Cost/unit
8   PLANT07   0.371424
17  PLANT04   0.428503
1   PLANT17   0.428947
13  PLANT09   0.465071
15  PLANT13   0.469707
4   PLANT02   0.477504
3   PLANT05   0.488144
7   PLANT10   0.493582
14  PLANT03   0.517502
16  PLANT08   0.522857
6   PLANT06   0.554088
12  PLANT11   0.555247
5   PLANT01   0.566976
9   PLANT14   0.634330
11  PLANT12   0.773132
0   PLANT15   1.415063
10  PLANT16   1.919808
2   PLANT18   2.036254
```

```
import matplotlib.pyplot as plt

# Filter out the TOTAL row from df_combined_sorted
# and assign it to df_filtered
df_filtered = df_combined_sorted[df_combined_sorted["Warehouse"] != "TOTAL"]

# Plot the bar chart for Warehouse vs Initial Orders
plt.figure(figsize=(12, 6))
plt.bar(df_filtered["Warehouse"], df_filtered["Max Capacity"], color='brown')
plt.xlabel("Warehouse")
plt.ylabel("Max Capacity")
plt.title("Max Capacity per Warehouse")
plt.xticks(rotation=90)
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show the plot
plt.show()
```



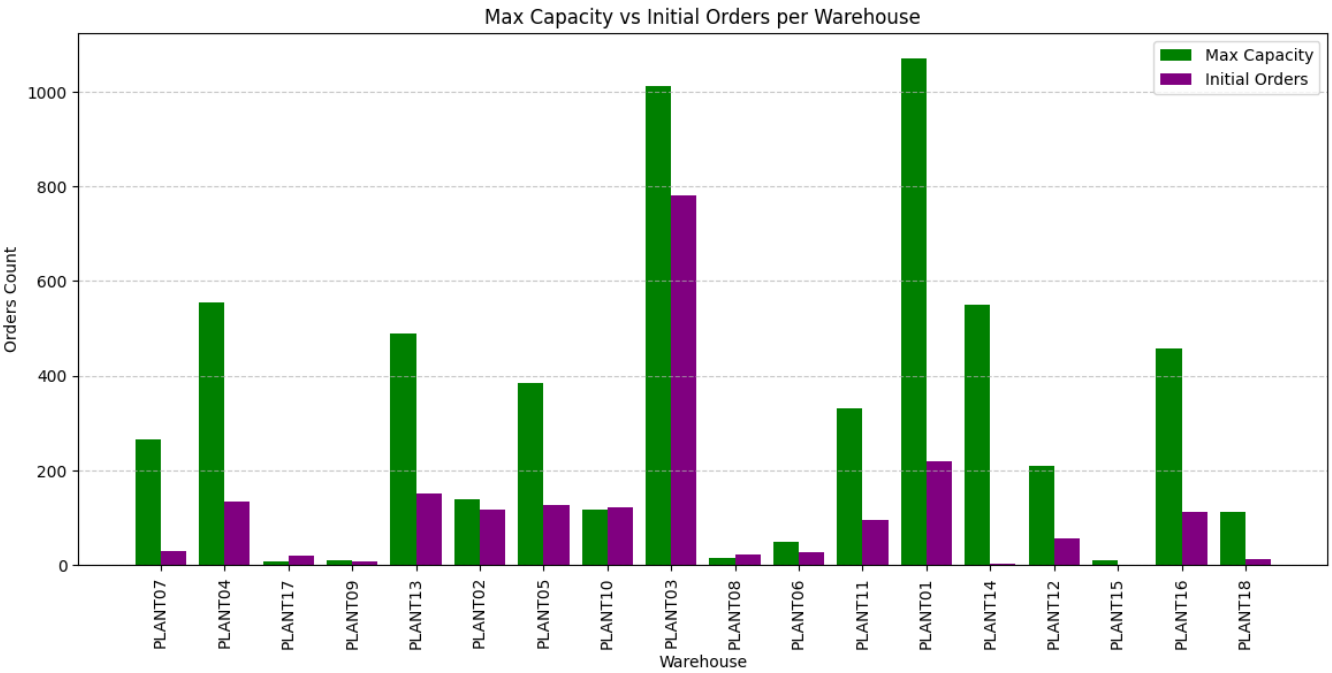

```
import matplotlib.pyplot as plt

# Filter out the TOTAL row from df_combined_sorted
# and assign it to df_filtered
df_filtered = df_combined_sorted[df_combined_sorted["Warehouse"] != "TOTAL"]

# Plot the bar chart for Warehouse vs Initial Orders
plt.figure(figsize=(12, 6))
plt.bar(df_filtered["Warehouse"], df_filtered["Initial Orders"], color='blue')
plt.xlabel("Warehouse")
plt.ylabel("Initial Orders")
plt.title("Initial Orders per Warehouse")
plt.xticks(rotation=90)
plt.grid(axis='y', linestyle='--', alpha=0.7)
```

```
# Show the plot
plt.show()
```

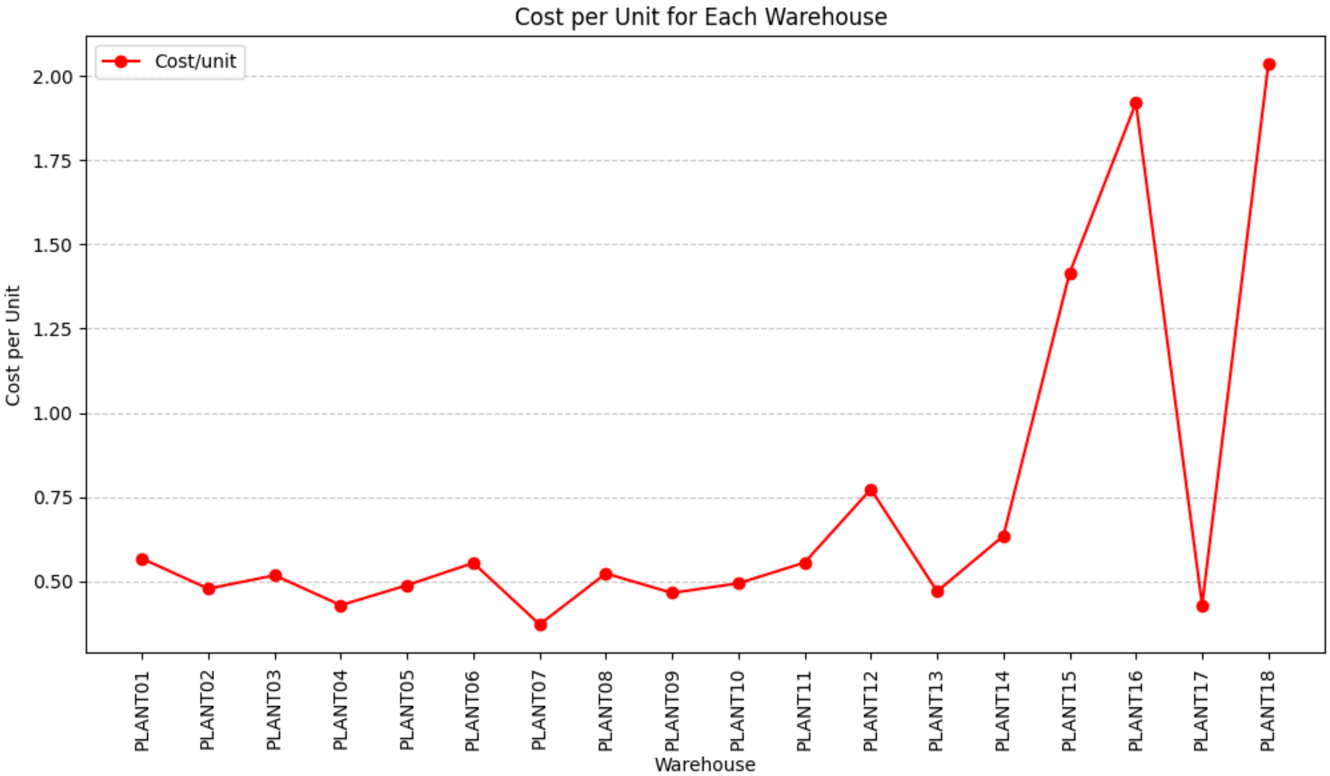



```
import matplotlib.pyplot as plt
import numpy as np

# Filter out the TOTAL row
df_filtered = df_combined_sorted[df_combined_sorted["Warehouse"] != "TOTAL"]

# Set width of bars
bar_width = 0.4
x_indexes = np.arange(len(df_filtered["Warehouse"]))

# Create bar chart with two bars side by side
```

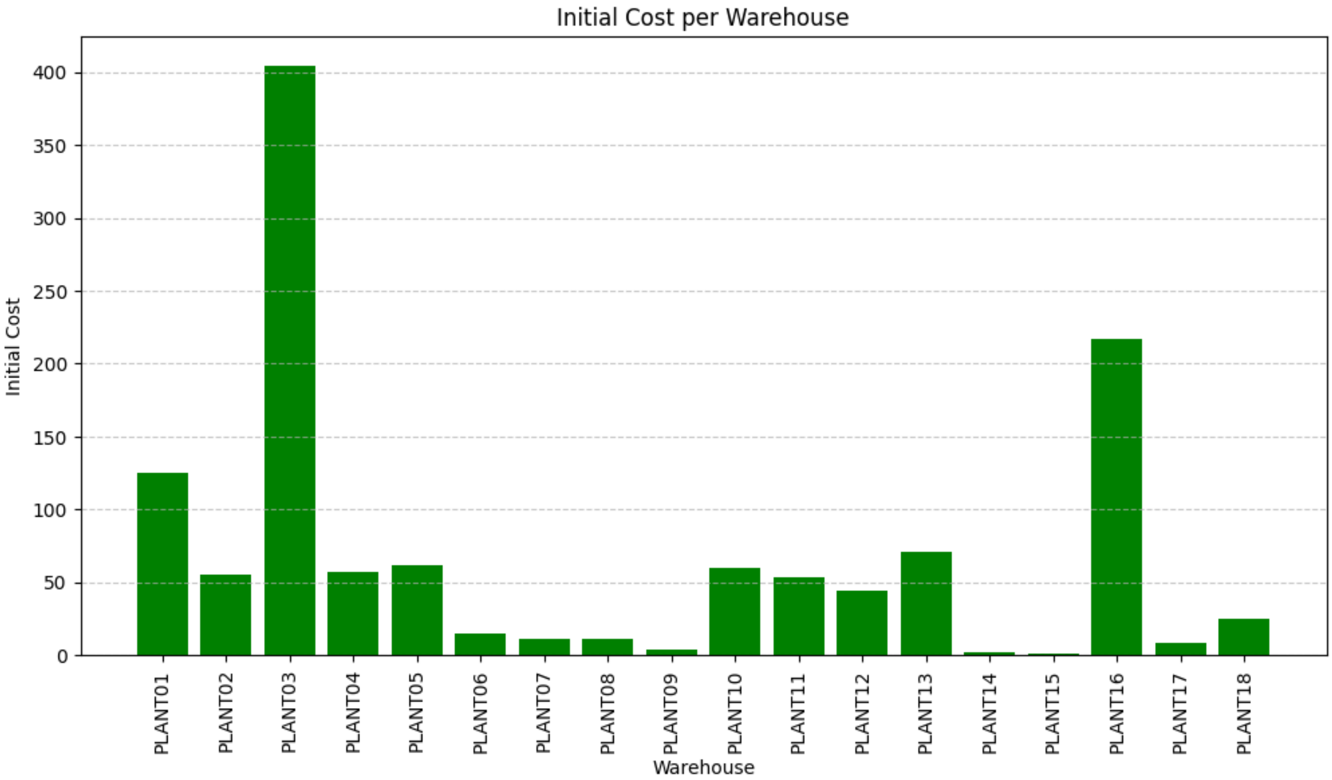
```
plt.figure(figsize=(14, 6))
plt.bar(x_indexes - bar_width/2, df_filtered["Max Capacity"], width=bar_width,
plt.bar(x_indexes + bar_width/2, df_filtered["Initial Orders"], width=bar_widtl

# Add labels and title
plt.xlabel("Warehouse")
plt.ylabel("Orders Count")
plt.title("Max Capacity vs Initial Orders per Warehouse")
plt.xticks(ticks=x_indexes, labels=df_filtered["Warehouse"], rotation=90)
plt.legend()
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
plt.show()
```



```
# Filter out the TOTAL row and sort by Warehouse in numerical order
df_filtered_sorted = df_filtered.sort_values(by="Warehouse", key=lambda x: x.st

# Plot the line graph for Warehouse vs Cost/unit
plt.figure(figsize=(12, 6))
plt.plot(df_filtered_sorted["Warehouse"], df_filtered_sorted["Cost/unit"], mark

plt.xlabel("Warehouse")
plt.ylabel("Cost per Unit")
plt.title("Cost per Unit for Each Warehouse ")
plt.xticks(rotation=90)
plt.grid(axis='y', linestyle='--', alpha=0.7)
plt.legend()

# Show the plot
plt.show()
```


Cost per Unit for Each Warehouse
Cost/unit
2.00
1.75
1.50
1.25
1.00
0.75
0.50
Cost per Unit
PLANT01
PLANT02
PLANT03
PLANT04
PLANT05
PLANT06
PLANT07
PLANT08
PLANT09
PLANT10
PLANT11
PLANT12
PLANT13
PLANT14
PLANT15
PLANT16
PLANT17
PLANT18
Warehouse

```
# Plot the bar chart for Warehouse vs Initial Cost
plt.figure(figsize=(12, 6))
plt.bar(df_filtered_sorted["Warehouse"], df_filtered_sorted["Initial Cost"], col

plt.xlabel("Warehouse")
plt.ylabel("Initial Cost")
plt.title("Initial Cost per Warehouse")
plt.xticks(rotation=90)
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show the plot
plt.show()
```



```
# Extract total initial cost from the "TOTAL" row of df_combined_sorted
total_initial_cost = df_combined_sorted[df_combined_sorted["Warehouse"] == "TOT

# Round the total cost for better readability
total_initial_cost_rounded = round(total_initial_cost, 2)

# Print the result
print(f"\n💰 Total Cost for Warehouse Utilization: {total_initial_cost_rounded}
```

```
💰 Total Cost for Warehouse Utilization: 1224.41
```

OPTIMIZATION USING ALGORITHMS

Genetic Algorithm

```
# Install DEAP (if not already installed)
!pip install deap

import numpy as np
import random
import pandas as pd
from deap import base, creator, tools, algorithms

# Load the Excel file
xls = pd.read_excel('/content/Supply chain logisitcs problem.xlsx', sheet_name=

# Load relevant tables
wh_capacities = xls["WhCapacities"]  # Warehouse capacities
wh_costs = xls["WhCosts"]  # Warehouse costs per unit
products_per_plant = xls["ProductsPerPlant"]  # Product-Warehouse compatibility
order_list = xls["OrderList"]  # Historical orders

# **Filter Valid Warehouses**
valid_warehouses = set(wh_capacities["Plant ID"])  # Only warehouses from the c

wh_capacities_dict = dict(zip(wh_capacities["Plant ID"], wh_capacities["Daily C
wh_costs_dict = dict(zip(wh_costs["WH"], wh_costs["Cost/unit"]))

# Sort warehouses by cost (ascending order) to prioritize cheaper warehouses
sorted_warehouses = sorted(wh_costs_dict.keys(), key=lambda x: wh_costs_dict[x]
```

```
# Process Product-Warehouse Compatibility
product_warehouse_map = {}
product_allocations_needed = {}

for _, row in products_per_plant.iterrows():
    product_id = row["Product ID"]
    plant_code = row["Plant Code"]

    if plant_code not in valid_warehouses:
        continue  # Skip invalid warehouses

    if product_id not in product_warehouse_map:
        product_warehouse_map[product_id] = []
    product_warehouse_map[product_id].append(plant_code)

    # Track how many times this product needs to be allocated
    product_allocations_needed[product_id] = product_allocations_needed.get(pro

# Total allocations required (should be 2036)
total_allocations_needed = sum(product_allocations_needed.values())

# Process Demand per Product
product_demand = order_list.groupby("Product ID")["Unit quantity"].sum().to_dic

# **Avoid Duplicate Creator Definitions**
if "FitnessMin" not in creator.__dict__:
    creator.create("FitnessMin", base.Fitness, weights=(-1.0,))
if "Individual" not in creator.__dict__:
    creator.create("Individual", list, fitness=creator.FitnessMin)

# Genetic Algorithm Setup
POP_SIZE = 100  # Increased population size
NGEN = 200  # More generations for stability
CXPB, MUTPB = 0.7, 0.2  # Crossover and mutation probability

# Define Individual Generation with Cost Optimization
def generate_individual():
    """Generate a valid warehouse allocation while ensuring cost-efficient allo
    individual = []
    warehouse_usage = {wh: 0 for wh in wh_capacities_dict.keys()}  # Track ware

    for product, required_allocations in product_allocations_needed.items():
        valid_warehouses = product_warehouse_map.get(product, [])
        valid_warehouses = [wh for wh in valid_warehouses if wh in wh_capacitie

        if not valid_warehouses:
            continue  # Skip products without valid warehouses
```

```
        # Sort warehouses for each product by lowest cost
        sorted_valid_warehouses = sorted(valid_warehouses, key=lambda x: wh_cos

        # Allocate product multiple times within warehouse constraints
        for _ in range(required_allocations):
            available_warehouses = [wh for wh in sorted_valid_warehouses if war
            chosen_warehouse = available_warehouses[0] if available_warehouses
            individual.append((product, chosen_warehouse))
            warehouse_usage[chosen_warehouse] += 1

    return individual

# **Updated GA Fitness Function to Prioritize Cost-Efficient Warehouses**
def evaluate(individual):
    """Evaluate cost efficiency while ensuring warehouse capacity is respected.

    warehouse_usage = {wh: 0 for wh in wh_capacities_dict.keys()}  # Track ware
    total_cost = 0
    assigned_products = {}  # Track assigned products
    PENALTY_UNASSIGNED = 1e10  # Stronger penalty for missing allocations
    PENALTY_OVERLOAD = 1e9  # Stronger penalty for exceeding warehouse capacity

    for product, warehouse in individual:
        if warehouse in wh_costs_dict and product in product_demand:
            demand = product_demand[product]
            storage_cost = wh_costs_dict[warehouse] * demand
            warehouse_usage[warehouse] += 1  # Increment order count
            total_cost += storage_cost

            # Track how many times a product was assigned
            assigned_products[product] = assigned_products.get(product, 0) + 1

    # **Apply penalty if warehouse exceeds capacity**
    overload_penalty = sum(PENALTY_OVERLOAD * (usage - wh_capacities_dict[wh])
                           for wh, usage in warehouse_usage.items() if usage >

    total_cost += overload_penalty

    # **Apply penalty for missing allocations**
    missing_allocations = sum(
        (required_allocations - assigned_products.get(product, 0))
        for product, required_allocations in product_allocations_needed.items()
    )

    total_cost += PENALTY_UNASSIGNED * missing_allocations  # Heavy penalty for

    return (total_cost,)
```

```
# Run Genetic Algorithm
toolbox = base.Toolbox()
toolbox.register("individual", tools.initIterate, creator.Individual, generate_
toolbox.register("population", tools.initRepeat, list, toolbox.individual)
toolbox.register("mate", tools.cxTwoPoint)
toolbox.register("mutate", tools.mutShuffleIndexes, indpb=0.2)
toolbox.register("select", tools.selTournament, tournsize=3)
toolbox.register("evaluate", evaluate)

population = toolbox.population(n=POP_SIZE)
hof = tools.HallOfFame(1)
stats = tools.Statistics(lambda ind: ind.fitness.values)
stats.register("min", np.min)
stats.register("avg", np.mean)

algorithms.eaSimple(population, toolbox, cxpb=CXPB, mutpb=MUTPB, ngen=NGEN, sta

# Extract Best Solution
best_solution = hof[0]
best_solution_df = pd.DataFrame(best_solution, columns=["Product ID", "Assignec

# **Check Warehouse Capacity Usage**
warehouse_usage_final = {wh: 0 for wh in wh_capacities_dict.keys()}  # Initiali

for product, warehouse in best_solution:
    if warehouse in warehouse_usage_final:
        warehouse_usage_final[warehouse] += 1  # Increment order count

warehouse_validation_df = pd.DataFrame(warehouse_usage_final.items(), columns=[
warehouse_validation_df["Max Capacity"] = warehouse_validation_df["Warehouse"].
warehouse_validation_df["Capacity Exceeded"] = warehouse_validation_df["Assigne

# Print Final Warehouse Validation Report
print("\n✅ **Final Warehouse Capacity Validation Report:**")
print(warehouse_validation_df)

print("\n **Optimization Complete! Cost-efficient allocation achieved with all
```

```
162     79      1.60268e+10     4.11778e+10
163     75      1.0027e+10      3.66974e+10
164     80      1.10272e+10     3.05773e+10
165     72      1.10272e+10     2.56074e+10
166     87      8.0259e+09      2.17972e+10
167     73      5.02679e+09     1.72473e+10
168     80      3.0258e+09      1.42672e+10
169     74      1.02555e+09     1.11568e+10
170     71      2.73315e+07     1.04965e+10
171     83      2.64322e+07     8.71612e+09
```

```
172     76      2.55172e+07     5.92591e+09
173     74      2.45371e+07     4.0759e+09
174     71      2.34323e+07     3.77576e+09
175     76      2.34323e+07     2.27558e+09
176     75      2.32944e+07     1.58553e+09
177     72      2.29073e+07     1.65483e+09
178     86      2.29073e+07     2.23433e+09
179     80      2.24675e+07     1.28406e+09
180     77      2.23349e+07     8.73593e+08
181     83      2.22336e+07     1.06324e+09
182     78      2.16364e+07     6.82918e+08
183     79      2.1132e+07      9.42449e+08
184     79      1.98165e+07     5.81985e+08
185     74      1.95292e+07     3.11475e+08
186     74      1.91561e+07     1.11101e+09
187     76      1.85326e+07     9.20483e+08
188     81      1.80628e+07     5.99945e+08
189     73      1.76075e+07     8.29561e+08
190     81      1.75961e+07     4.39204e+08
191     73      1.74442e+07     1.10876e+09
192     71      1.72052e+07     3.88342e+08
193     69      1.6536e+07      6.4796e+08
194     75      1.61425e+07     1.09744e+09
195     76      1.60393e+07     4.0708e+08
196     74      1.49567e+07     2.56747e+08
197     76      1.45228e+07     3.5635e+08
198     71      1.45228e+07     2.86039e+08
199     84      1.42612e+07     5.2557e+08
200     73      1.40368e+07     3.95228e+08

✅ **Final Warehouse Capacity Validation Report:**
   Warehouse  Assigned Orders  Max Capacity  Capacity Exceeded
0    PLANT15                0            11              False
1    PLANT17                0             8              False
2    PLANT18                0           111              False
3    PLANT05               88           385              False
4    PLANT02              113           138              False
5    PLANT01                0          1070              False
6    PLANT06                0            49              False
7    PLANT10              116           118              False
8    PLANT07               39           265              False
9    PLANT14                0           549              False
10   PLANT16               25           457              False
11   PLANT12              201           209              False
12   PLANT11                0           332              False
13   PLANT09                6            11              False
14   PLANT03              957          1013              False
15   PLANT13              134           490              False
16   PLANT08                0            14              False
```

Number of Unallocated Warehouses

```
# Count unallocated warehouses
unallocated_warehouses1 = sum(1 for wh, usage in warehouse_usage_final.items()
print(f"\n📊 Number of Unallocated Warehouses: {unallocated_warehouses1}")
```

```
📊 Number of Unallocated Warehouses: 8
```

Cost Analysis

```
# Remove existing TOTAL row before merging to avoid duplication
df_combined_sorted = df_combined_sorted[df_combined_sorted["Warehouse"] != "TOT

# Merge DBO results with the initial warehouse table
df_final = pd.merge(df_combined_sorted, warehouse_validation_df, on="Warehouse"

# Drop duplicate Max Capacity column
df_final.drop(columns=["Max Capacity_y"], inplace=True)

# Rename Max Capacity column for clarity
df_final.rename(columns={"Max Capacity_x": "Max Capacity"}, inplace=True)

# Add Optimized Cost column (Assigned Orders * Cost/unit)
df_final["Optimized Cost"] = df_final["Assigned Orders"] * df_final["Cost/unit"

# Create a single TOTAL row with all summed values
total_row = pd.DataFrame([{
    "Warehouse": "TOTAL",
    "Max Capacity": df_final["Max Capacity"].sum(),
    "Initial Orders": df_final["Initial Orders"].sum(),
    "Cost/unit": None,
    "Initial Cost": df_final["Initial Cost"].sum(),
    "Assigned Orders": df_final["Assigned Orders"].sum(),
    "Capacity Exceeded": None,
    "Optimized Cost": df_final["Optimized Cost"].sum()
}])

# Append the new TOTAL row
df_final_sorted1 = pd.concat([df_final, total_row], ignore_index=True)

# Reorder columns for final output
df_final_sorted1 = df_final_sorted1[[
    "Warehouse", "Max Capacity", "Initial Orders", "Cost/unit", "Initial Cost",
    "Assigned Orders", "Capacity Exceeded", "Optimized Cost"
]]

# Display the final report
```

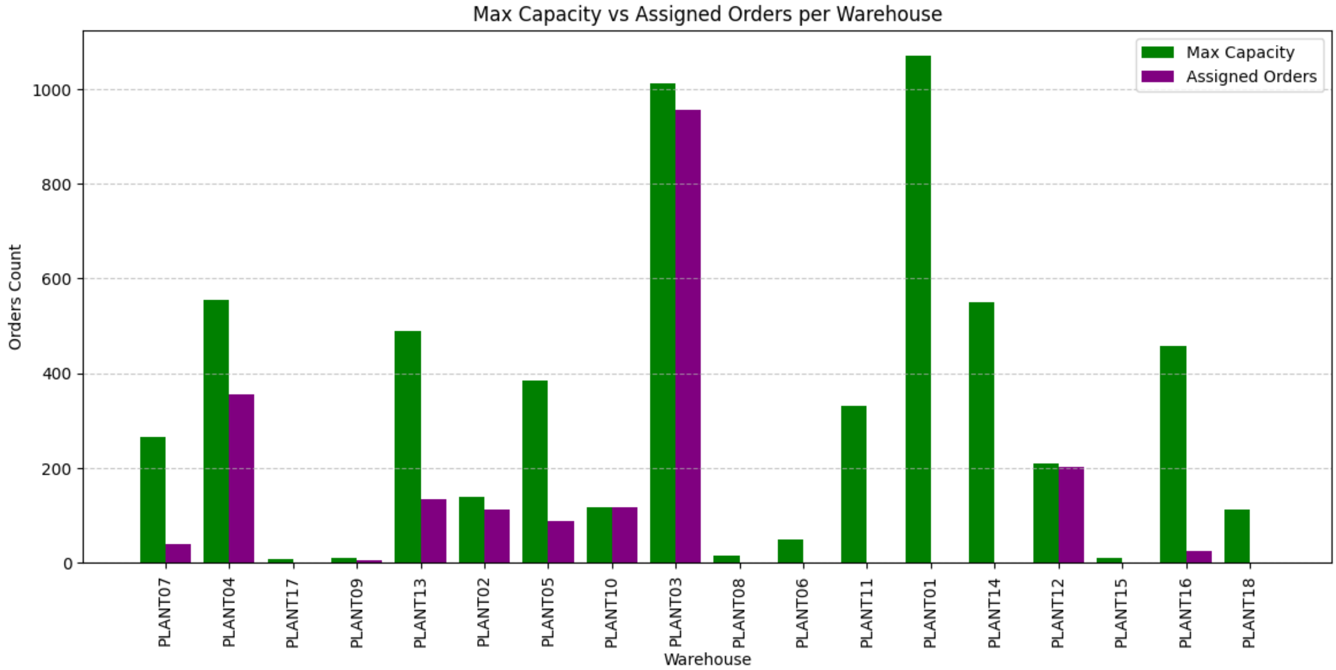
```
display(df_final_sorted1)
```

```
<ipython-input-14-1697473a23f5>:29: FutureWarning: The behavior of DataFram
  df_final_sorted1 = pd.concat([df_final, total_row], ignore_index=True)
```

	Warehouse	Max Capacity	Initial Orders	Cost/unit	Initial Cost	Assigned Orders	Capacity Exceeded
0	PLANT07	265	29	0.371424	10.771294	39	False
1	PLANT04	554	134	0.428503	57.419442	356	False
2	PLANT17	8	20	0.428947	8.578932	0	False
3	PLANT09	11	8	0.465071	3.720569	6	False
4	PLANT13	490	150	0.469707	70.456058	134	False
5	PLANT02	138	116	0.477504	55.390408	113	False
6	PLANT05	385	127	0.488144	61.994337	88	False
7	PLANT10	118	121	0.493582	59.723410	116	False
8	PLANT03	1013	781	0.517502	404.168977	957	False
9	PLANT08	14	21	0.522857	10.980003	0	False
10	PLANT06	49	26	0.554088	14.406291	0	False
11	PLANT11	332	96	0.555247	53.303740	0	False
12	PLANT01	1070	220	0.566976	124.734761	0	False
13	PLANT14	549	3	0.634330	1.902989	0	False
14	PLANT12	209	57	0.773132	44.068512	201	False
15	PLANT15	11	1	1.415063	1.415063	0	False
16	PLANT16	457	113	1.919808	216.938248	25	False
17	PLANT18	111	12	2.036254	24.435045	0	False
18	TOTAL	5784	2035	NaN	1224.408080	2035	None

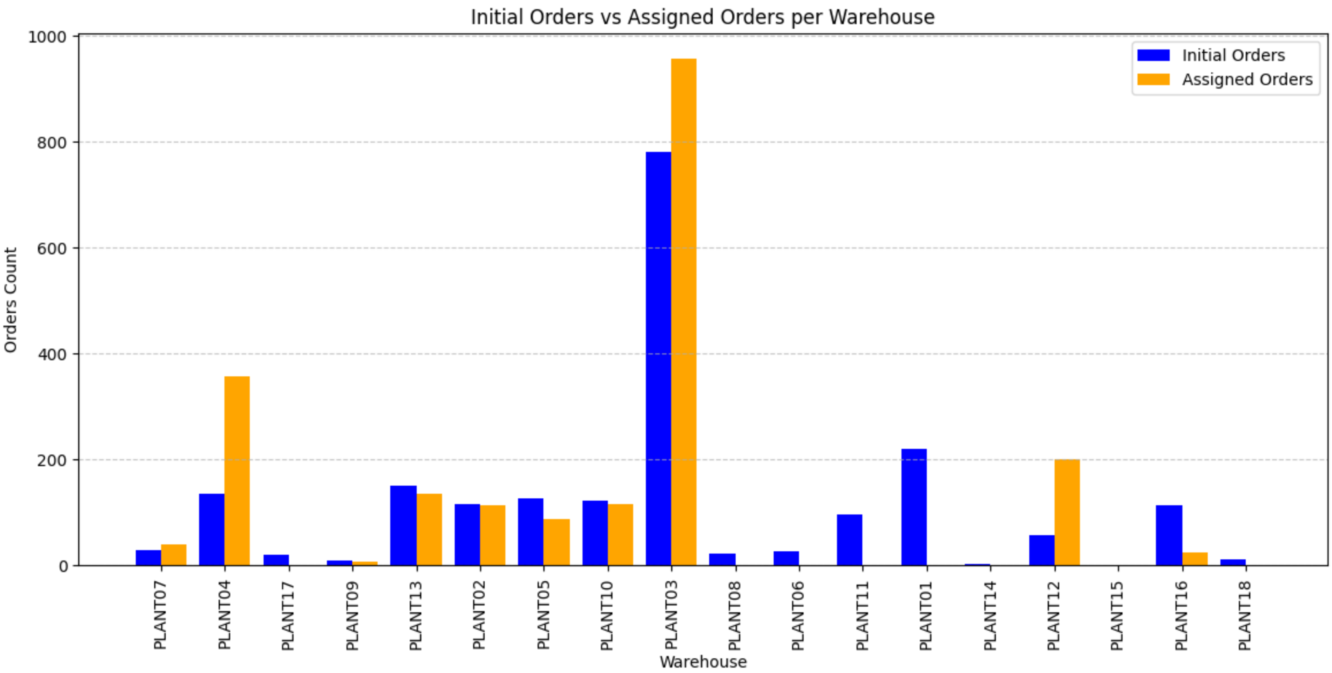
```
import matplotlib.pyplot as plt
import numpy as np

# Filter out the TOTAL row
df_filtered = df_final_sorted1[df_final_sorted1["Warehouse"] != "TOTAL"]

# Set width of bars
bar_width = 0.4
```

```
x_indexes = np.arange(len(df_filtered["Warehouse"]))

# Create bar chart with two bars side by side
plt.figure(figsize=(14, 6))
plt.bar(x_indexes - bar_width/2, df_filtered["Max Capacity"], width=bar_width,
plt.bar(x_indexes + bar_width/2, df_filtered["Assigned Orders"], width=bar_widt

# Add labels and title
plt.xlabel("Warehouse")
plt.ylabel("Orders Count")
plt.title("Max Capacity vs Assigned Orders per Warehouse")
plt.xticks(ticks=x_indexes, labels=df_filtered["Warehouse"], rotation=90)
plt.legend()
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
plt.show()
```



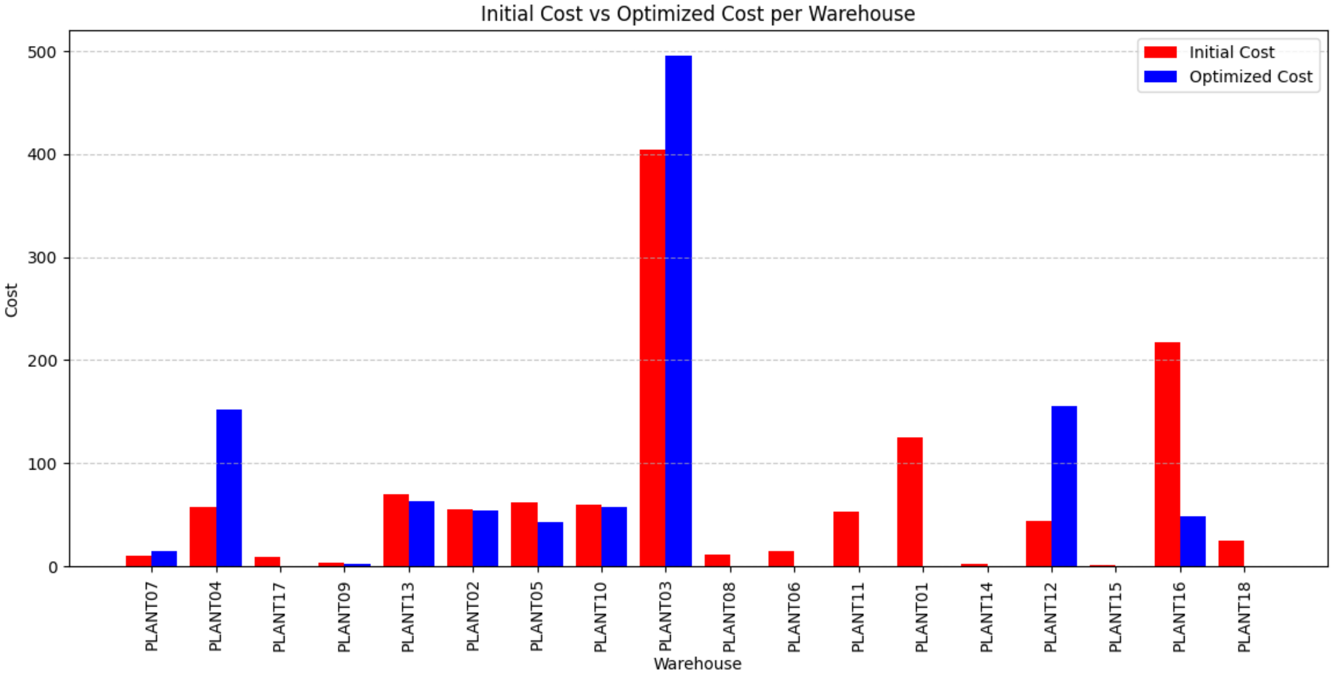

```
import matplotlib.pyplot as plt
import numpy as np

# Filter out the TOTAL row
df_filtered = df_final_sorted1[df_final_sorted1["Warehouse"] != "TOTAL"]

# Set width of bars
bar_width = 0.4
x_indexes = np.arange(len(df_filtered["Warehouse"]))

# Create bar chart with two bars side by side
plt.figure(figsize=(14, 6))
plt.bar(x_indexes - bar_width/2, df_filtered["Initial Orders"], width=bar_widtl
plt.bar(x_indexes + bar_width/2, df_filtered["Assigned Orders"], width=bar_widt
```

```
# Add labels and title
plt.xlabel("Warehouse")
plt.ylabel("Orders Count")
plt.title("Initial Orders vs Assigned Orders per Warehouse")
plt.xticks(ticks=x_indexes, labels=df_filtered["Warehouse"], rotation=90)
plt.legend()
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
plt.show()
```



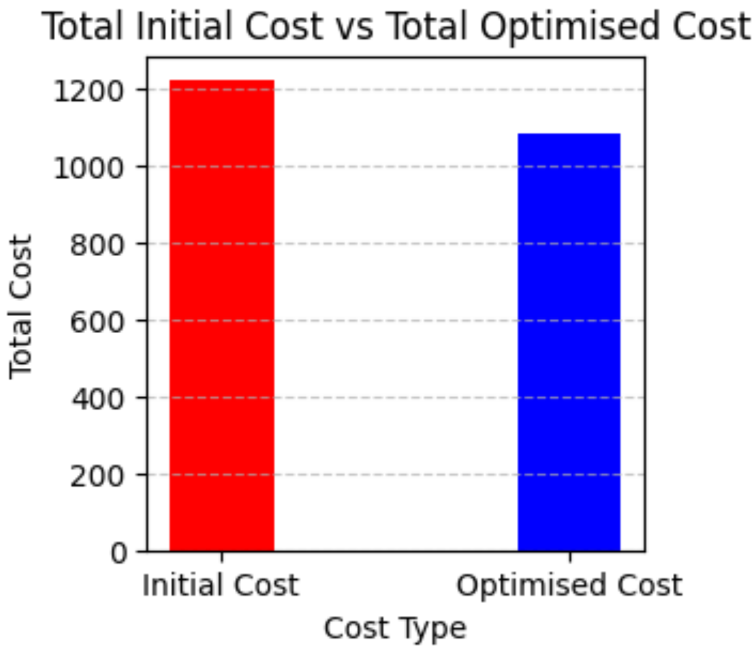

```
import matplotlib.pyplot as plt
import numpy as np
```

```
# Filter out the TOTAL row
df_filtered = df_final_sorted1[df_final_sorted1["Warehouse"] != "TOTAL"]

# Set width of bars
bar_width = 0.4
x_indexes = np.arange(len(df_filtered["Warehouse"]))

# Create bar chart with two bars side by side
plt.figure(figsize=(14, 6))
plt.bar(x_indexes - bar_width/2, df_filtered["Initial Cost"], width=bar_width,
plt.bar(x_indexes + bar_width/2, df_filtered["Optimized Cost"], width=bar_widtl

# Add labels and title
plt.xlabel("Warehouse")
plt.ylabel("Cost")
plt.title("Initial Cost vs Optimized Cost per Warehouse") # Changed "Optimised
plt.xticks(ticks=x_indexes, labels=df_filtered["Warehouse"], rotation=90)
plt.legend()
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
plt.show()
```



Total Cost Reduction & Cost Reduction Percentage

```
import matplotlib.pyplot as plt

# Extract total values from the final sorted dataframe
total_initial_cost = df_final_sorted1[df_final_sorted1["Warehouse"] == "TOTAL"]
total_optimized_cost = df_final_sorted1[df_final_sorted1["Warehouse"] == "TOTAL

# Define labels and values
labels = ["Initial Cost", "Optimised Cost"]
values = [total_initial_cost, total_optimized_cost]
colors = ["red", "blue"]

# Create bar chart
plt.figure(figsize=(3, 3))
plt.bar(labels, values, color=colors, width=0.3)

# Add labels and title
plt.xlabel("Cost Type")
plt.ylabel("Total Cost")
plt.title("Total Initial Cost vs Total Optimised Cost")
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
plt.show()
```



```
# Calculate total cost reduction and cost reduction percentage
total_initial_cost1 = df_final_sorted1[df_final_sorted1["Warehouse"] == "TOTAL'
total_optimized_cost1 = df_final_sorted1[df_final_sorted1["Warehouse"] == "TOT/

total_cost_reduction1 = (total_initial_cost1 - total_optimized_cost1) # This li
cost_reduction_percentage1 = (total_cost_reduction1 / total_initial_cost1) * 1(

# Print the results
print(f"\n💰 Total Cost Reduction: {total_cost_reduction1:.2f}")
print(f"📉 Cost Reduction Percentage: {cost_reduction_percentage1:.2f}%")
```

```
💰 Total Cost Reduction: 138.83
📉 Cost Reduction Percentage: 11.34%
```

Ant Colony Optimization Algorithm

```
import numpy as np
import pandas as pd
import random

# Load the Excel file
xls = pd.ExcelFile('/content/Supply chain logisitcs problem.xlsx')

# Load relevant tables
wh_capacities = pd.read_excel(xls, "WhCapacities")  # Warehouse capacities
wh_costs = pd.read_excel(xls, "WhCosts")  # Warehouse costs per unit
products_per_plant = pd.read_excel(xls, "ProductsPerPlant")  # Product-Warehous
order_list = pd.read_excel(xls, "OrderList")  # Historical orders

# Convert warehouse capacities and costs into dictionaries
wh_capacities_dict = dict(zip(wh_capacities["Plant ID"], wh_capacities["Daily (
wh_costs_dict = dict(zip(wh_costs["WH"], wh_costs["Cost/unit"]))

# Process Product-Warehouse Compatibility
product_warehouse_map = {}
product_allocations_needed = {}

for _, row in products_per_plant.iterrows():
    product_id = row["Product ID"]
    plant_code = row["Plant Code"]

    if plant_code not in wh_capacities_dict:
        continue  # Skip invalid warehouses
```

```
        if product_id not in product_warehouse_map:
            product_warehouse_map[product_id] = []
        product_warehouse_map[product_id].append(plant_code)

        product_allocations_needed[product_id] = product_allocations_needed.get(pro

# Process Demand per Product
product_demand = order_list.groupby("Product ID")["Unit quantity"].sum().to_dic

# Ant Colony Optimization Parameters
NUM_ANTS = 50  # Number of ants in the colony
NUM_ITERATIONS = 200  # Number of iterations for optimization
ALPHA = 1  # Influence of pheromone
BETA = 3  # Stronger bias toward cost minimization
EVAPORATION_RATE = 0.3  # Lower evaporation to retain good solutions longer
Q = 500  # Higher pheromone deposit factor for best solutions

# Initialize pheromone levels (higher initial value = more exploration)
tau = {wh: 1.0 for wh in wh_capacities_dict.keys()}  # Pheromone levels per war

# Function to evaluate a solution
def evaluate_solution(solution):
    warehouse_usage = {wh: 0 for wh in wh_capacities_dict.keys()}
    total_cost = 0
    penalty = 1e9  # High penalty for constraint violations

    for product, warehouse in solution:
        if warehouse in wh_costs_dict and product in product_demand:
            demand = product_demand[product]
            cost = wh_costs_dict[warehouse] * demand
            total_cost += cost
            warehouse_usage[warehouse] += 1

    # Apply penalty for warehouse overuse
    for wh, usage in warehouse_usage.items():
        if usage > wh_capacities_dict[wh]:
            total_cost += penalty * (usage - wh_capacities_dict[wh])  # Penaliz

    return total_cost

# Function to construct a solution with **strict least-cost prioritization**
def construct_solution():
    solution = []
    warehouse_usage = {wh: 0 for wh in wh_capacities_dict.keys()}

    for product, required_allocations in product_allocations_needed.items():
        valid_warehouses = product_warehouse_map.get(product, [])
        warehouse_options = []
```

```
        # Prioritize least-cost warehouses while respecting pheromones
        for wh in valid_warehouses:
            if wh in wh_costs_dict:
                cost = wh_costs_dict[wh]
                heuristic = 1 / (cost + 1e-6)  # **Strong bias toward lowest co
                warehouse_options.append((wh, cost, (tau[wh]**ALPHA) * (heurist

        # Sort warehouses **strictly** by cost (Lowest first)
        warehouse_options = sorted(warehouse_options, key=lambda x: x[1])

        for _ in range(required_allocations):
            allocated = False
            for wh, cost, prob in warehouse_options:
                if warehouse_usage[wh] < wh_capacities_dict[wh]:  # Ensure capa
                    solution.append((product, wh))
                    warehouse_usage[wh] += 1
                    allocated = True
                    break  # Stop once allocated successfully

            # If all preferred warehouses are full, assign to **next cheapest**
            if not allocated:
                available_warehouses = sorted(
                    [(wh, wh_costs_dict[wh]) for wh in wh_capacities_dict.keys(
                    key=lambda x: x[1]  # Sort by cost again
                )

                if available_warehouses:
                    chosen_warehouse = available_warehouses[0][0]  # Assign to
                    solution.append((product, chosen_warehouse))
                    warehouse_usage[chosen_warehouse] += 1

    return solution

# ACO Main Optimization Loop
best_solution = None
best_cost = float('inf')

for iteration in range(NUM_ITERATIONS):
    solutions = []
    costs = []

    for _ in range(NUM_ANTS):
        solution = construct_solution()
        cost = evaluate_solution(solution)
        solutions.append(solution)
        costs.append(cost)
```

```
    # Update pheromones
    for wh in tau.keys():
        tau[wh] *= (1 - EVAPORATION_RATE)  # Pheromone evaporation

    best_index = np.argmin(costs)
    if costs[best_index] < best_cost:
        best_solution = solutions[best_index]
        best_cost = costs[best_index]

    for product, warehouse in best_solution:
        tau[warehouse] += Q / best_cost  # Pheromone deposit for the best solut

    print(f"Iteration {iteration + 1}: Best Cost = {best_cost}")

# Convert best solution to DataFrame
best_solution_df = pd.DataFrame(best_solution, columns=["Product ID", "Assignec

# Validate Warehouse Capacities
warehouse_usage_final = {wh: 0 for wh in wh_capacities_dict.keys()}
for product, warehouse in best_solution:
    warehouse_usage_final[warehouse] += 1

warehouse_validation_df = pd.DataFrame(warehouse_usage_final.items(), columns=[
warehouse_validation_df["Max Capacity"] = warehouse_validation_df["Warehouse"].
warehouse_validation_df["Capacity Exceeded"] = warehouse_validation_df["Assigne

print("\n✅ **Final Warehouse Capacity Validation Report:**")
print(warehouse_validation_df)

# Final Validation
if warehouse_validation_df["Capacity Exceeded"].any():
    print("\n❌ **Issue: Some warehouses exceed capacity! Debug needed.**")
else:
    print("\n🎉 **Optimization Complete! Strict least-cost allocation achieved
```

```
Iteration 105: Best Cost = 17872037.94663344
Iteration 106: Best Cost = 17872037.94663344
Iteration 107: Best Cost = 17872037.94663344
Iteration 108: Best Cost = 17872037.94663344
Iteration 109: Best Cost = 17872037.94663344
Iteration 110: Best Cost = 17872037.94663344
Iteration 111: Best Cost = 17872037.94663344
Iteration 112: Best Cost = 17872037.94663344
Iteration 113: Best Cost = 17872037.94663344
Iteration 114: Best Cost = 17872037.94663344
Iteration 115: Best Cost = 17872037.94663344
Iteration 116: Best Cost = 17872037.94663344
Iteration 117: Best Cost = 17872037.94663344
```

```
Iteration 118: Best Cost = 17872037.94663344
Iteration 119: Best Cost = 17872037.94663344
Iteration 120: Best Cost = 17872037.94663344
Iteration 121: Best Cost = 17872037.94663344
Iteration 122: Best Cost = 17872037.94663344
Iteration 123: Best Cost = 17872037.94663344
Iteration 124: Best Cost = 17872037.94663344
Iteration 125: Best Cost = 17872037.94663344
Iteration 126: Best Cost = 17872037.94663344
Iteration 127: Best Cost = 17872037.94663344
Iteration 128: Best Cost = 17872037.94663344
Iteration 129: Best Cost = 17872037.94663344
Iteration 130: Best Cost = 17872037.94663344
Iteration 131: Best Cost = 17872037.94663344
Iteration 132: Best Cost = 17872037.94663344
Iteration 133: Best Cost = 17872037.94663344
Iteration 134: Best Cost = 17872037.94663344
Iteration 135: Best Cost = 17872037.94663344
Iteration 136: Best Cost = 17872037.94663344
Iteration 137: Best Cost = 17872037.94663344
Iteration 138: Best Cost = 17872037.94663344
Iteration 139: Best Cost = 17872037.94663344
Iteration 140: Best Cost = 17872037.94663344
Iteration 141: Best Cost = 17872037.94663344
Iteration 142: Best Cost = 17872037.94663344
Iteration 143: Best Cost = 17872037.94663344
Iteration 144: Best Cost = 17872037.94663344
Iteration 145: Best Cost = 17872037.94663344
Iteration 146: Best Cost = 17872037.94663344
Iteration 147: Best Cost = 17872037.94663344
Iteration 148: Best Cost = 17872037.94663344
Iteration 149: Best Cost = 17872037.94663344
Iteration 150: Best Cost = 17872037.94663344
Iteration 151: Best Cost = 17872037.94663344
Iteration 152: Best Cost = 17872037.94663344
Iteration 153: Best Cost = 17872037.94663344
Iteration 154: Best Cost = 17872037.94663344
Iteration 155: Best Cost = 17872037.94663344
Iteration 156: Best Cost = 17872037.94663344
Iteration 157: Best Cost = 17872037.94663344
Iteration 158: Best Cost = 17872037.94663344
Iteration 159: Best Cost = 17872037.94663344
Iteration 160: Best Cost = 17872037.94663344
Iteration 161: Best Cost = 17872037.94663344
Iteration 162: Best Cost = 17872037.94663344
Iteration 163: Best Cost = 17872037.94663344
```

Number of Unallocated Warehouses

```
# Count unallocated warehouses
unallocated_warehouses2 = sum(1 for wh, usage in warehouse_usage_final.items()
print(f"\n📊 Number of Unallocated Warehouses: {unallocated_warehouses2}")
```

```
📊 Number of Unallocated Warehouses: 2
```

Cost Analysis

```
# Remove existing TOTAL row before merging to avoid duplication
df_combined_sorted = df_combined_sorted[df_combined_sorted["Warehouse"] != "TOT

# Merge DBO results with the initial warehouse table
df_final = pd.merge(df_combined_sorted, warehouse_validation_df, on="Warehouse"

# Drop duplicate Max Capacity column
df_final.drop(columns=["Max Capacity_y"], inplace=True)

# Rename Max Capacity column for clarity
df_final.rename(columns={"Max Capacity_x": "Max Capacity"}, inplace=True)

# Add Optimized Cost column (Assigned Orders * Cost/unit)
df_final["Optimized Cost"] = df_final["Assigned Orders"] * df_final["Cost/unit"

# Create a single TOTAL row with all summed values
total_row = pd.DataFrame([{
    "Warehouse": "TOTAL",
    "Max Capacity": df_final["Max Capacity"].sum(),
    "Initial Orders": df_final["Initial Orders"].sum(),
    "Cost/unit": None,
    "Initial Cost": df_final["Initial Cost"].sum(),
    "Assigned Orders": df_final["Assigned Orders"].sum(),
    "Capacity Exceeded": None,
    "Optimized Cost": df_final["Optimized Cost"].sum()
}])

# Append the new TOTAL row
df_final_sorted2 = pd.concat([df_final, total_row], ignore_index=True)

# Reorder columns for final output
df_final_sorted2 = df_final_sorted2[[
    "Warehouse", "Max Capacity", "Initial Orders", "Cost/unit", "Initial Cost",
    "Assigned Orders", "Capacity Exceeded", "Optimized Cost"
]]

# Display the final report
```

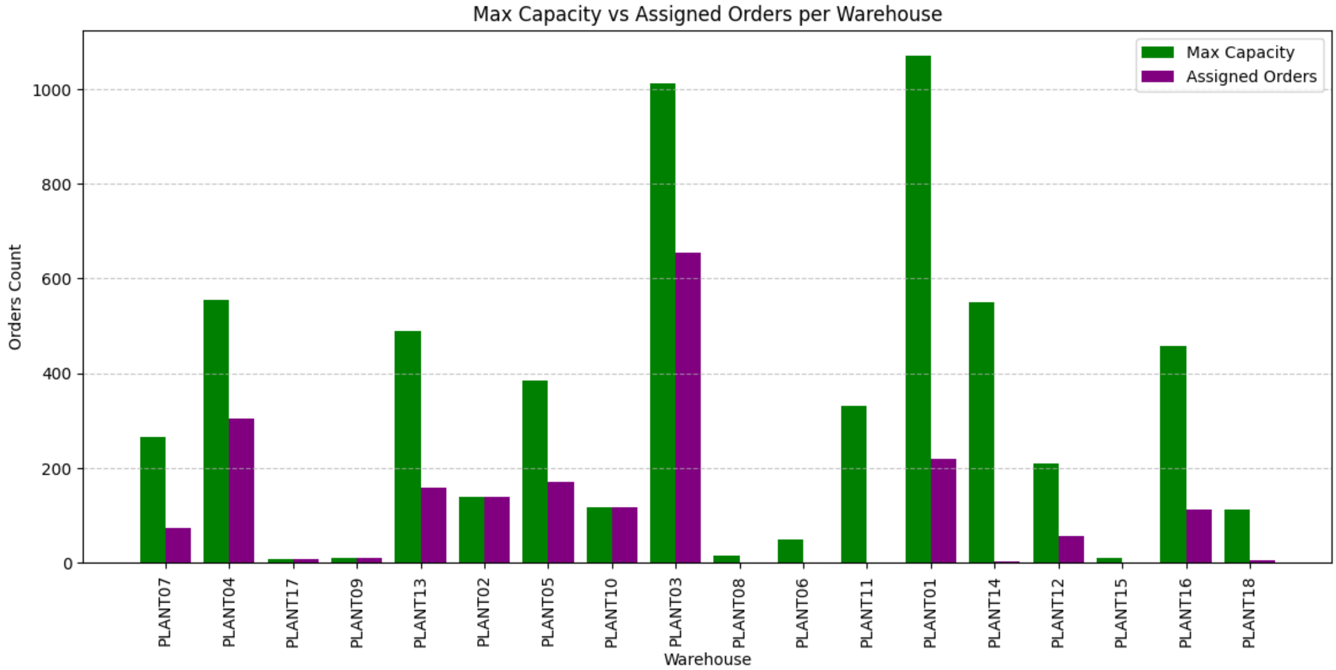
```
display(df_final_sorted2)
```

```
<ipython-input-9-37eee550e930>:29: FutureWarning: The behavior of DataFrame
  df_final_sorted2 = pd.concat([df_final, total_row], ignore_index=True)
```

	Warehouse	Max Capacity	Initial Orders	Cost/unit	Initial Cost	Assigned Orders	Capacity Exceeded
0	PLANT07	265	29	0.371424	10.771294	74	False
1	PLANT04	554	134	0.428503	57.419442	303	False
2	PLANT17	8	20	0.428947	8.578932	8	False
3	PLANT09	11	8	0.465071	3.720569	11	False
4	PLANT13	490	150	0.469707	70.456058	159	False
5	PLANT02	138	116	0.477504	55.390408	138	False
6	PLANT05	385	127	0.488144	61.994337	171	False
7	PLANT10	118	121	0.493582	59.723410	118	False
8	PLANT03	1013	781	0.517502	404.168977	655	False
9	PLANT08	14	21	0.522857	10.980003	1	False
10	PLANT06	49	26	0.554088	14.406291	0	False
11	PLANT11	332	96	0.555247	53.303740	0	False
12	PLANT01	1070	220	0.566976	124.734761	220	False
13	PLANT14	549	3	0.634330	1.902989	2	False
14	PLANT12	209	57	0.773132	44.068512	55	False
15	PLANT15	11	1	1.415063	1.415063	1	False
16	PLANT16	457	113	1.919808	216.938248	113	False
17	PLANT18	111	12	2.036254	24.435045	6	False
18	TOTAL	5784	2035	NaN	1224.408080	2035	None

```
import matplotlib.pyplot as plt
import numpy as np

# Filter out the TOTAL row
df_filtered = df_final_sorted2[df_final_sorted2["Warehouse"] != "TOTAL"] # Char

# Set width of bars
bar_width = 0.4
```

```
x_indexes = np.arange(len(df_filtered["Warehouse"]))

# Create bar chart with two bars side by side
plt.figure(figsize=(14, 6))
plt.bar(x_indexes - bar_width/2, df_filtered["Max Capacity"], width=bar_width,
plt.bar(x_indexes + bar_width/2, df_filtered["Assigned Orders"], width=bar_widt

# Add labels and title
plt.xlabel("Warehouse")
plt.ylabel("Orders Count")
plt.title("Max Capacity vs Assigned Orders per Warehouse")
plt.xticks(ticks=x_indexes, labels=df_filtered["Warehouse"], rotation=90)
plt.legend()
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
plt.show()
```




```
import matplotlib.pyplot as plt
import numpy as np

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plt.figure(figsize=(14, 6))
plt.bar(x_indexes - bar_width/2, df_filtered["Initial Orders"], width=bar_widtl
plt.bar(x_indexes + bar_width/2, df_filtered["Assigned Orders"], width=bar_widt
```
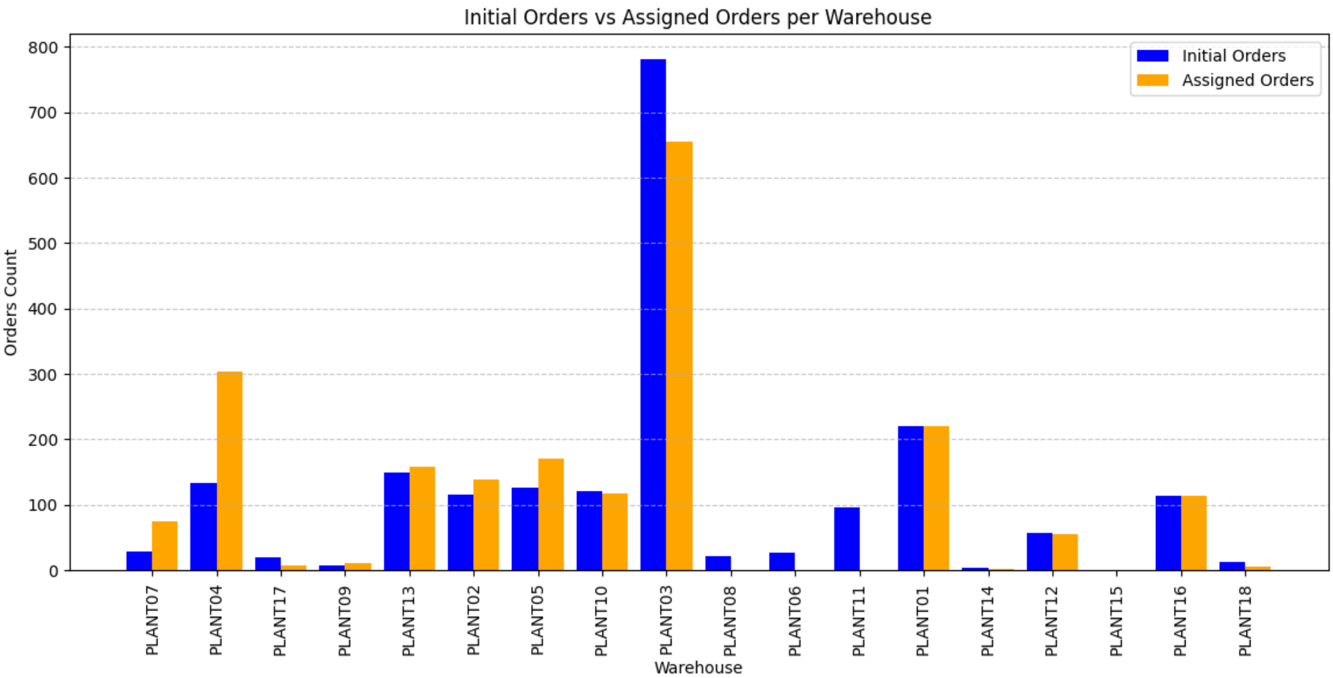
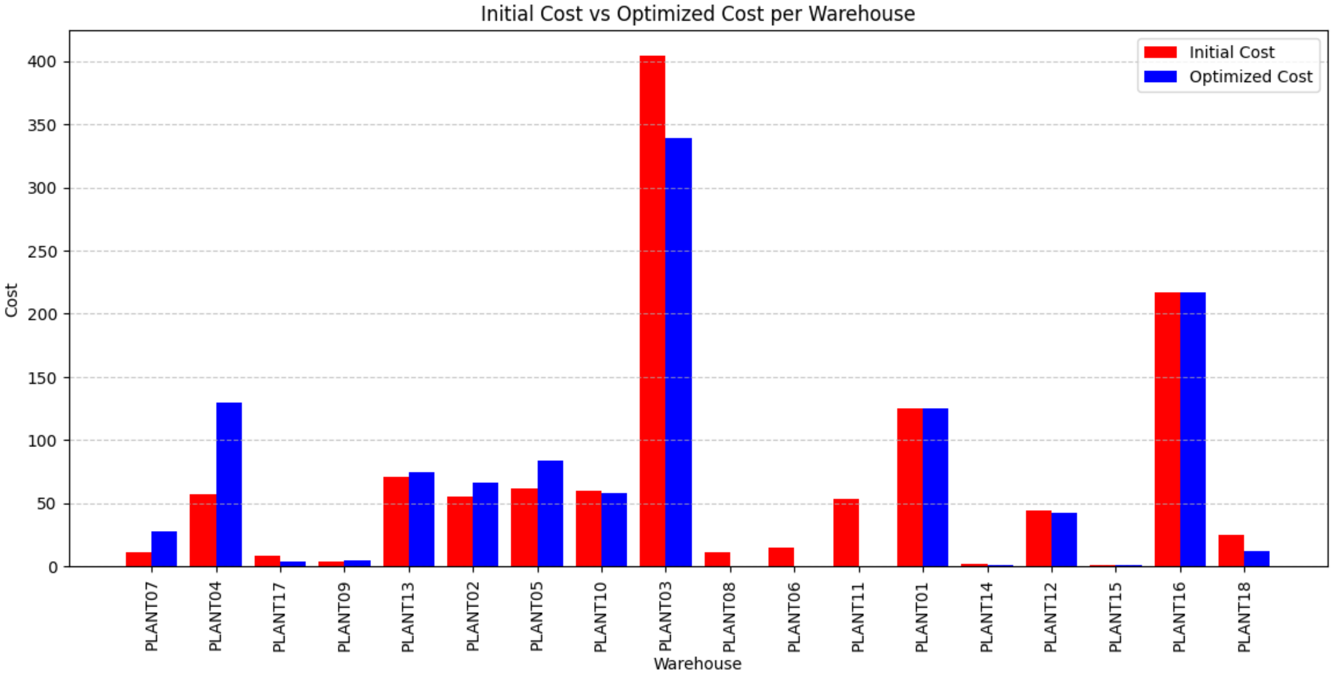

```
# Add labels and title
plt.xlabel("Warehouse")
plt.ylabel("Orders Count")
plt.title("Initial Orders vs Assigned Orders per Warehouse")
plt.xticks(ticks=x_indexes, labels=df_filtered["Warehouse"], rotation=90)
plt.legend()
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
plt.show()
```



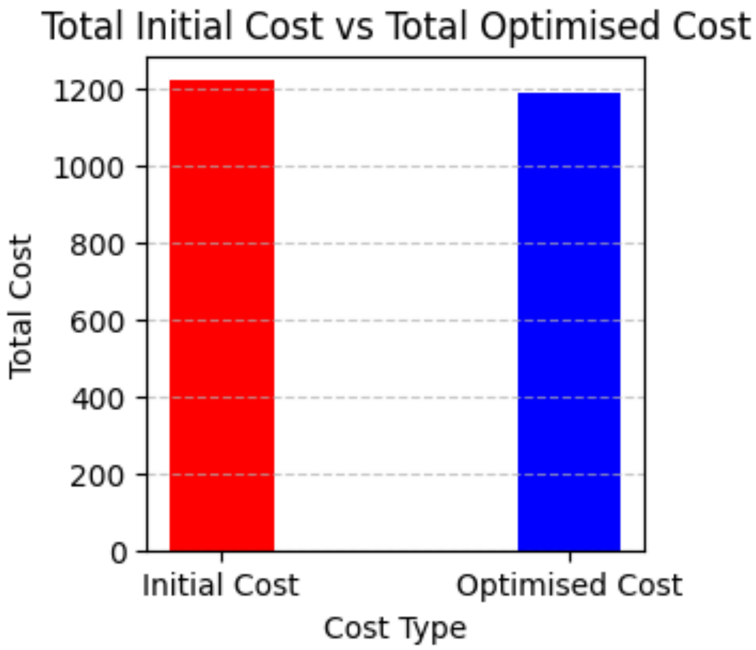

```
import matplotlib.pyplot as plt
import numpy as np
```

```
# Filter out the TOTAL row
df_filtered = df_final_sorted2[df_final_sorted2["Warehouse"] != "TOTAL"]

# Set width of bars
bar_width = 0.4
x_indexes = np.arange(len(df_filtered["Warehouse"]))

# Create bar chart with two bars side by side
plt.figure(figsize=(14, 6))
plt.bar(x_indexes - bar_width/2, df_filtered["Initial Cost"], width=bar_width,
plt.bar(x_indexes + bar_width/2, df_filtered["Optimized Cost"], width=bar_widtl

# Add labels and title
plt.xlabel("Warehouse")
plt.ylabel("Cost")
plt.title("Initial Cost vs Optimized Cost per Warehouse") # Changed "Optimised
plt.xticks(ticks=x_indexes, labels=df_filtered["Warehouse"], rotation=90)
plt.legend()
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
plt.show()
```



Total Cost Reduction & Cost Reduction Percentage

```
import matplotlib.pyplot as plt

# Extract total values from the final sorted dataframe
total_initial_cost = df_final_sorted2[df_final_sorted2["Warehouse"] == "TOTAL"]
total_optimized_cost = df_final_sorted2[df_final_sorted2["Warehouse"] == "TOTAL

# Define labels and values
labels = ["Initial Cost", "Optimised Cost"]
values = [total_initial_cost, total_optimized_cost]
colors = ["red", "blue"]

# Create bar chart
plt.figure(figsize=(3, 3))
plt.bar(labels, values, color=colors, width=0.3)

# Add labels and title
plt.xlabel("Cost Type")
plt.ylabel("Total Cost")
plt.title("Total Initial Cost vs Total Optimised Cost")
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
plt.show()
```



```
# Calculate total cost reduction and cost reduction percentage
total_initial_cost2 = df_final_sorted2[df_final_sorted2["Warehouse"] == "TOTAL'
total_optimized_cost2 = df_final_sorted2[df_final_sorted2["Warehouse"] == "TOT/

total_cost_reduction2 = total_initial_cost2 - total_optimized_cost2
cost_reduction_percentage2 = (total_cost_reduction2 / total_initial_cost2) * 1(

# Print the results
print(f"\n💰 Total Cost Reduction: {total_cost_reduction2:.2f}")
print(f"📉 Cost Reduction Percentage: {cost_reduction_percentage2:.2f}%")
```

```
💰 Total Cost Reduction: 37.66
📉 Cost Reduction Percentage: 3.08%
```

Dung Beetle Optimization Algorithm

```
import numpy as np
import pandas as pd
import heapq  # For efficient least-cost warehouse selection

# Load the Excel file
xls = pd.ExcelFile('/content/Supply chain logisitcs problem.xlsx')

# Load relevant tables
wh_capacities = pd.read_excel(xls, "WhCapacities")  # Warehouse capacities
wh_costs = pd.read_excel(xls, "WhCosts")  # Warehouse costs per unit
products_per_plant = pd.read_excel(xls, "ProductsPerPlant")  # Product-Warehous
order_list = pd.read_excel(xls, "OrderList")  # Historical orders

# Convert warehouse capacities and costs into dictionaries
wh_capacities_dict = dict(zip(wh_capacities["Plant ID"], wh_capacities["Daily (
wh_costs_dict = dict(zip(wh_costs["WH"], wh_costs["Cost/unit"]))

# Process Product-Warehouse Compatibility
product_warehouse_map = {}
product_allocations_needed = {}

for _, row in products_per_plant.iterrows():
    product_id = row["Product ID"]
    plant_code = row["Plant Code"]

    if plant_code not in wh_capacities_dict:
        continue  # Skip invalid warehouses
```

```
        if product_id not in product_warehouse_map:
            product_warehouse_map[product_id] = []
        product_warehouse_map[product_id].append(plant_code)

        product_allocations_needed[product_id] = product_allocations_needed.get(prc

# Process Demand per Product
product_demand = order_list.groupby("Product ID")["Unit quantity"].sum().to_dic

# Dung Beetle Optimization Parameters
POP_SIZE = 50  # Population size
MAX_ITER = 200  # Number of iterations
A = 1.5  # Attraction coefficient
B = 1.5  # Repulsion coefficient
C = 1.5  # Step size coefficient

# Function to evaluate a solution
def evaluate_solution(solution):
    warehouse_usage = {wh: 0 for wh in wh_capacities_dict.keys()}
    total_cost = 0
    penalty = 1e9  # High penalty for constraint violations

    for product, warehouse in solution:
        if warehouse in wh_costs_dict and product in product_demand:
            demand = product_demand[product]
            cost = wh_costs_dict[warehouse] * demand
            total_cost += cost
            warehouse_usage[warehouse] += 1

    # Apply penalty for warehouse overuse
    for wh, usage in warehouse_usage.items():
        if usage > wh_capacities_dict[wh]:
            total_cost += penalty * (usage - wh_capacities_dict[wh])  # Penaliz

    return total_cost

# Function to generate a valid initial solution (ensuring cost-efficiency)
def generate_solution():
    solution = []
    warehouse_usage = {wh: 0 for wh in wh_capacities_dict.keys()}
    remaining_products = 2035  # Ensure all products are allocated
    unassigned_products = []  # Track products that couldn't be allocated

    for product, required_allocations in product_allocations_needed.items():
        valid_warehouses = [(wh_costs_dict[wh], wh) for wh in product_warehouse
        heapq.heapify(valid_warehouses)  # Min-heap for least-cost selection

        allocations = 0
```

```
        while valid_warehouses and allocations < required_allocations:
            _, wh = heapq.heappop(valid_warehouses)  # Get least-cost warehouse
            if warehouse_usage[wh] < wh_capacities_dict[wh]:
                solution.append((product, wh))
                warehouse_usage[wh] += 1
                allocations += 1
                remaining_products -= 1

        if allocations < required_allocations:
            unassigned_products.append((product, required_allocations - allocat

    # Second pass: Assign unallocated products dynamically to nearest available
    for product, remaining in unassigned_products:
        valid_warehouses = sorted(wh_capacities_dict.keys(), key=lambda x: wh_c

        for wh in valid_warehouses:
            if warehouse_usage[wh] < wh_capacities_dict[wh] and remaining > 0:
                solution.append((product, wh))
                warehouse_usage[wh] += 1
                remaining -= 1
                remaining_products -= 1
            if remaining == 0:
                break  # Stop if fully assigned

    assert remaining_products == 0, f"Error: {remaining_products} products are
    return solution

# Initialize dung beetle population
population = [generate_solution() for _ in range(POP_SIZE)]
fitness = [evaluate_solution(ind) for ind in population]
best_solution = population[np.argmin(fitness)]
best_cost = min(fitness)

# Dung Beetle Optimization Loop
for iteration in range(MAX_ITER):
    new_population = []

    for i in range(POP_SIZE):
        leader = best_solution
        follower = population[i]

        new_solution = []
        warehouse_usage = {wh: 0 for wh in wh_capacities_dict.keys()}
        remaining_products = 2035  # Ensure all products are assigned

        for (product, warehouse) in follower:
            valid_warehouses = [(wh_costs_dict[wh], wh) for wh in product_wareh
            heapq.heapify(valid_warehouses)  # Min-heap for cost optimization
```

```
            if valid_warehouses:
                _, new_warehouse = heapq.heappop(valid_warehouses)  # Select le
            else:
                new_warehouse = warehouse

            new_solution.append((product, new_warehouse))
            warehouse_usage[new_warehouse] += 1
            remaining_products -= 1
            if remaining_products == 0:
                break

        new_population.append(new_solution)

    population = new_population
    fitness = [evaluate_solution(ind) for ind in population]

    if min(fitness) < best_cost:
        best_solution = population[np.argmin(fitness)]
        best_cost = min(fitness)

    print(f"Iteration {iteration + 1}: Best Cost = {best_cost}")

# Convert best solution to DataFrame
best_solution_df = pd.DataFrame(best_solution, columns=["Product ID", "Assignec

# Validate Warehouse Capacities
warehouse_usage_final = {wh: 0 for wh in wh_capacities_dict.keys()}
for product, warehouse in best_solution:
    warehouse_usage_final[warehouse] += 1

warehouse_validation_df = pd.DataFrame(warehouse_usage_final.items(), columns=|
warehouse_validation_df["Max Capacity"] = warehouse_validation_df["Warehouse"].
warehouse_validation_df["Capacity Exceeded"] = warehouse_validation_df["Assigne

# Validate total assigned products
total_assigned = warehouse_validation_df["Assigned Orders"].sum()
assert total_assigned == 2035, f"Error: Not all products were assigned! ({total

print("\n✅ **Final Warehouse Capacity Validation Report:**")
print(warehouse_validation_df)
print("\n🎉 **Optimization Complete! Cost-efficient allocation achieved with DI
```

```
Iteration 163: Best Cost = 17872037.94663344
Iteration 164: Best Cost = 17872037.94663344
Iteration 165: Best Cost = 17872037.94663344
Iteration 166: Best Cost = 17872037.94663344
```

```
Iteration 167: Best Cost = 17872037.94663344
Iteration 168: Best Cost = 17872037.94663344
Iteration 169: Best Cost = 17872037.94663344
Iteration 170: Best Cost = 17872037.94663344
Iteration 171: Best Cost = 17872037.94663344
Iteration 172: Best Cost = 17872037.94663344
Iteration 173: Best Cost = 17872037.94663344
Iteration 174: Best Cost = 17872037.94663344
Iteration 175: Best Cost = 17872037.94663344
Iteration 176: Best Cost = 17872037.94663344
Iteration 177: Best Cost = 17872037.94663344
Iteration 178: Best Cost = 17872037.94663344
Iteration 179: Best Cost = 17872037.94663344
Iteration 180: Best Cost = 17872037.94663344
Iteration 181: Best Cost = 17872037.94663344
Iteration 182: Best Cost = 17872037.94663344
Iteration 183: Best Cost = 17872037.94663344
Iteration 184: Best Cost = 17872037.94663344
Iteration 185: Best Cost = 17872037.94663344
Iteration 186: Best Cost = 17872037.94663344
Iteration 187: Best Cost = 17872037.94663344
Iteration 188: Best Cost = 17872037.94663344
Iteration 189: Best Cost = 17872037.94663344
Iteration 190: Best Cost = 17872037.94663344
Iteration 191: Best Cost = 17872037.94663344
Iteration 192: Best Cost = 17872037.94663344
Iteration 193: Best Cost = 17872037.94663344
Iteration 194: Best Cost = 17872037.94663344
Iteration 195: Best Cost = 17872037.94663344
Iteration 196: Best Cost = 17872037.94663344
Iteration 197: Best Cost = 17872037.94663344
Iteration 198: Best Cost = 17872037.94663344
Iteration 199: Best Cost = 17872037.94663344
Iteration 200: Best Cost = 17872037.94663344
```

✅ **Final Warehouse Capacity Validation Report:**

	Warehouse	Assigned Orders	Max Capacity	Capacity Exceeded
0	PLANT15	1	11	False
1	PLANT17	8	8	False
2	PLANT18	6	111	False
3	PLANT05	171	385	False
4	PLANT02	138	138	False
5	PLANT01	220	1070	False
6	PLANT06	0	49	False
7	PLANT10	118	118	False
8	PLANT07	74	265	False
9	PLANT14	2	549	False
10	PLANT16	113	457	False
11	PLANT12	55	209	False
12	PLANT11	0	332	False
13	PLANT09	11	11	False
14	PLANT03	655	1013	False
15	PLANT13	159	490	False

```
16    PLANT08                    1            14                 False
```

Number of Unallocated Warehouses

```
# Count unallocated warehouses
unallocated_warehouses3 = sum(1 for wh, usage in warehouse_usage_final.items()
print(f"\n📊 Number of Unallocated Warehouses: {unallocated_warehouses3}")
```

```
📊 Number of Unallocated Warehouses: 2
```

Cost Analysis

```
# Remove existing TOTAL row before merging to avoid duplication
df_combined_sorted = df_combined_sorted[df_combined_sorted["Warehouse"] != "TOT

# Merge DBO results with the initial warehouse table
df_final = pd.merge(df_combined_sorted, warehouse_validation_df, on="Warehouse"

# Drop duplicate Max Capacity column
df_final.drop(columns=["Max Capacity_y"], inplace=True)

# Rename Max Capacity column for clarity
df_final.rename(columns={"Max Capacity_x": "Max Capacity"}, inplace=True)

# Add Optimized Cost column (Assigned Orders * Cost/unit)
df_final["Optimized Cost"] = df_final["Assigned Orders"] * df_final["Cost/unit"

# Create a single TOTAL row with all summed values
total_row = pd.DataFrame([{
    "Warehouse": "TOTAL",
    "Max Capacity": df_final["Max Capacity"].sum(),
    "Initial Orders": df_final["Initial Orders"].sum(),
    "Cost/unit": None,
    "Initial Cost": df_final["Initial Cost"].sum(),
    "Assigned Orders": df_final["Assigned Orders"].sum(),
    "Capacity Exceeded": None,
    "Optimized Cost": df_final["Optimized Cost"].sum()
}])

# Append the new TOTAL row
df_final_sorted3 = pd.concat([df_final, total_row], ignore_index=True)

# Reorder columns for final output
df_final_sorted3 = df_final_sorted3[[
    "Warehouse", "Max Capacity", "Initial Orders", "Cost/unit", "Initial Cost",
```

```
    "Assigned Orders", "Capacity Exceeded", "Optimized Cost"
]]

# Display the final report
display(df_final_sorted3)
```

```
<ipython-input-116-5700baffe8ff>:29: FutureWarning: The behavior of DataFra
  df_final_sorted3 = pd.concat([df_final, total_row], ignore_index=True)
```

	Warehouse	Max Capacity	Initial Orders	Cost/unit	Initial Cost	Assigned Orders	Capacity Exceeded
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18	TOTAL	5784	2035	NaN	1224.408080	2035	None

```
import matplotlib.pyplot as plt
import numpy as np

# Filter out the TOTAL row
```

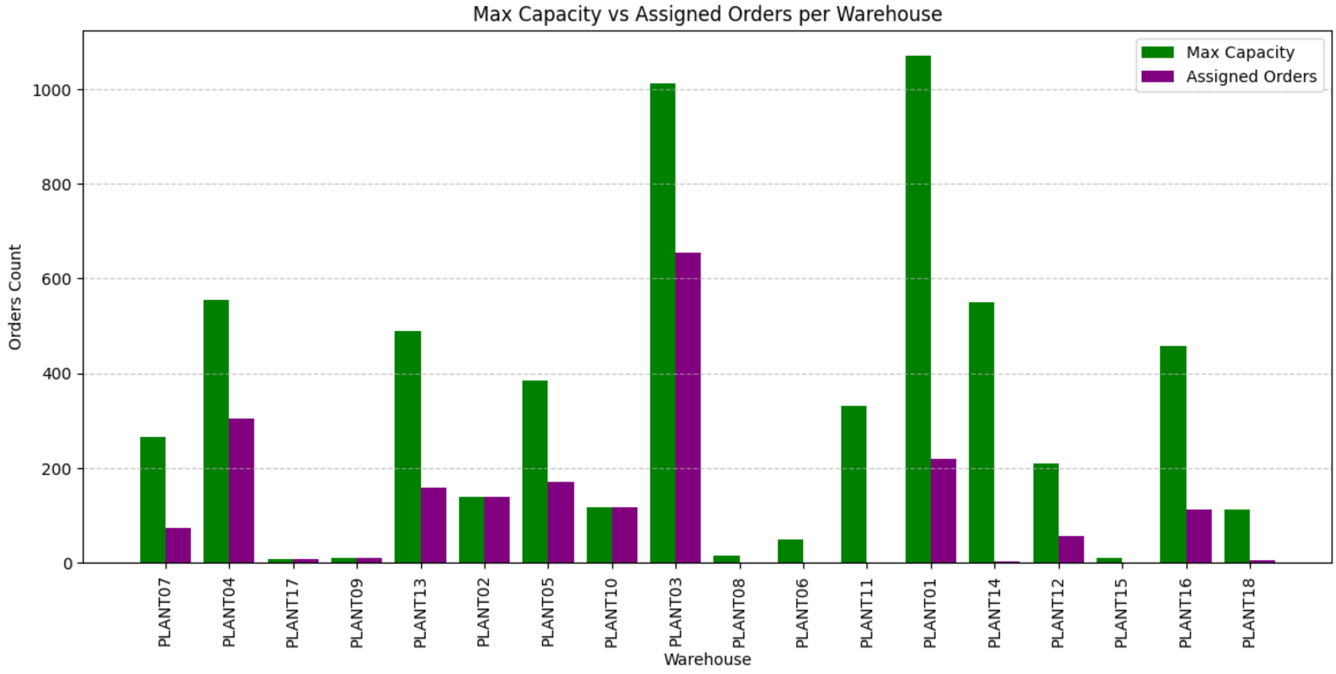
```
df_filtered = df_final_sorted3[df_final_sorted3["Warehouse"] != "TOTAL"]

# Set width of bars
bar_width = 0.4
x_indexes = np.arange(len(df_filtered["Warehouse"]))

# Create bar chart with two bars side by side
plt.figure(figsize=(14, 6))
plt.bar(x_indexes - bar_width/2, df_filtered["Max Capacity"], width=bar_width,
plt.bar(x_indexes + bar_width/2, df_filtered["Assigned Orders"], width=bar_widt

# Add labels and title
plt.xlabel("Warehouse")
plt.ylabel("Orders Count")
plt.title("Max Capacity vs Assigned Orders per Warehouse")
plt.xticks(ticks=x_indexes, labels=df_filtered["Warehouse"], rotation=90)
plt.legend()
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
plt.show()
```




```
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bar_width = 0.4
x_indexes = np.arange(len(df_filtered["Warehouse"]))

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plt.figure(figsize=(14, 6))
plt.bar(x_indexes - bar_width/2, df_filtered["Initial Orders"], width=bar_widt
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```

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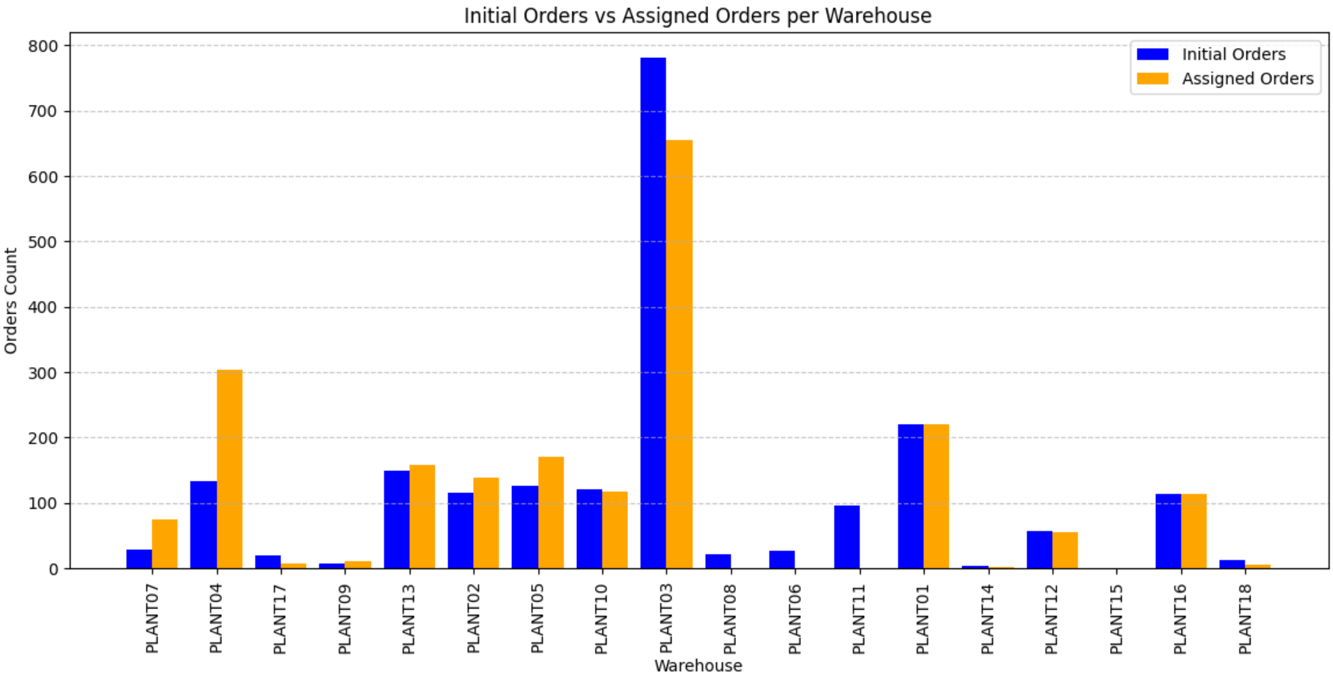
```

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import numpy as np
```

```
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# Set width of bars
bar_width = 0.4
x_indexes = np.arange(len(df_filtered["Warehouse"]))

# Create bar chart with two bars side by side
plt.figure(figsize=(14, 6))
plt.bar(x_indexes - bar_width/2, df_filtered["Initial Cost"], width=bar_width,
plt.bar(x_indexes + bar_width/2, df_filtered["Optimized Cost"], width=bar_widtl

# Add labels and title
plt.xlabel("Warehouse")
plt.ylabel("Cost")
plt.title("Initial Cost vs Optimized Cost per Warehouse") # Changed "Optimised
plt.xticks(ticks=x_indexes, labels=df_filtered["Warehouse"], rotation=90)
plt.legend()
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
plt.show()
```
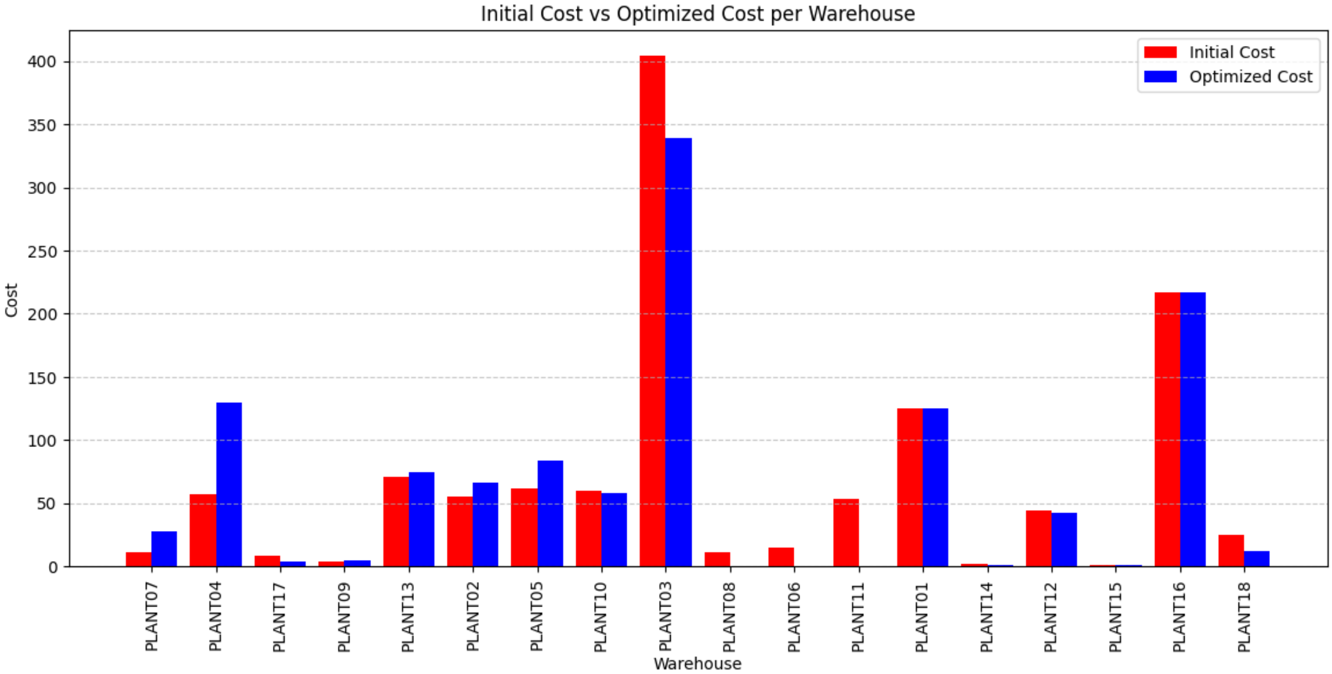
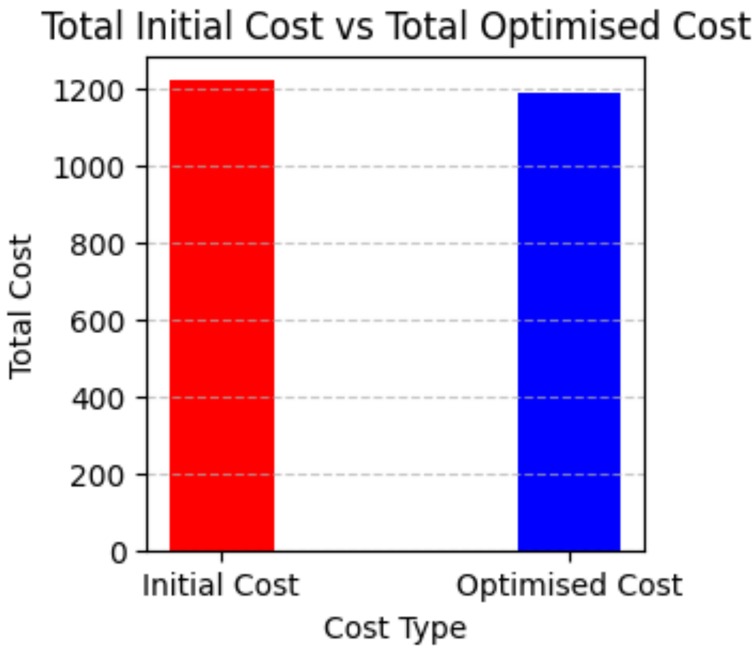



Total Cost Reduction & Cost Reduction Percentage

```
import matplotlib.pyplot as plt

# Extract total values from the final sorted dataframe
total_initial_cost = df_final_sorted3[df_final_sorted3["Warehouse"] == "TOTAL"]
total_optimized_cost = df_final_sorted3[df_final_sorted3["Warehouse"] == "TOTAL

# Define labels and values
labels = ["Initial Cost", "Optimised Cost"]
values = [total_initial_cost, total_optimized_cost]
colors = ["red", "blue"]

# Create bar chart
plt.figure(figsize=(3, 3))
plt.bar(labels, values, color=colors, width=0.3)

# Add labels and title
plt.xlabel("Cost Type")
plt.ylabel("Total Cost")
plt.title("Total Initial Cost vs Total Optimised Cost")
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
plt.show()
```



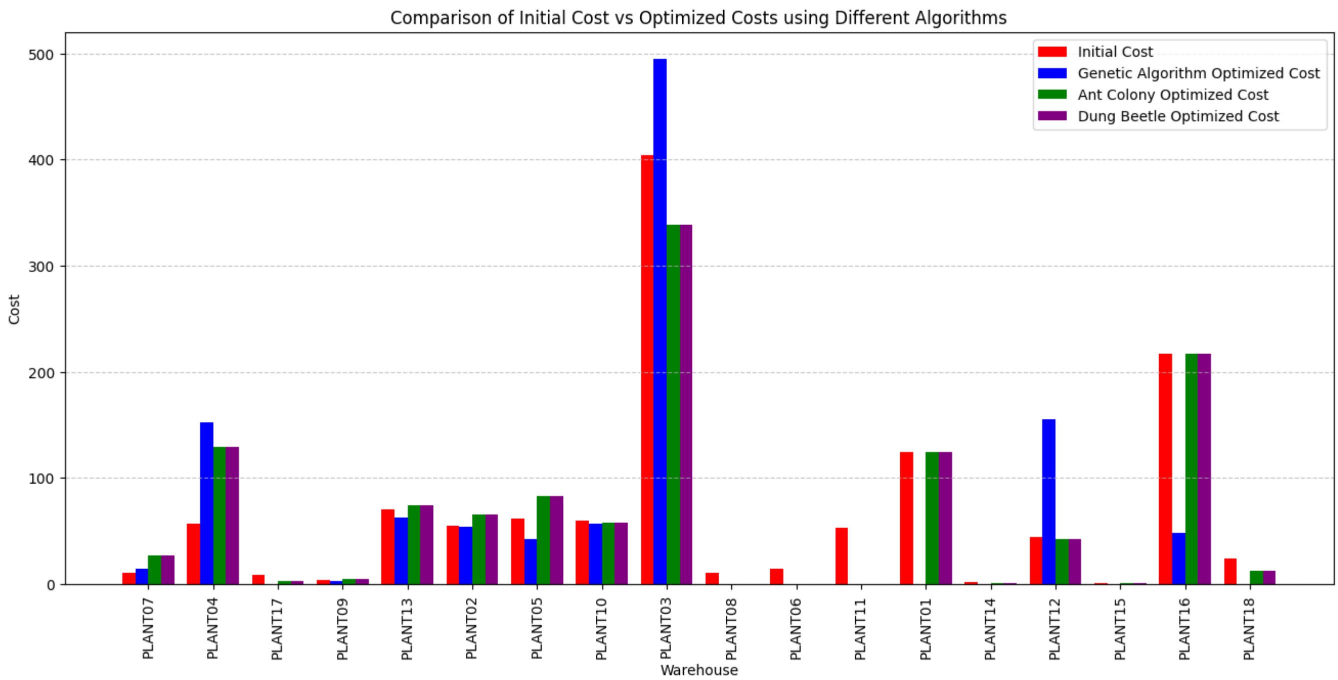
```
# Calculate total cost reduction and cost reduction percentage
total_initial_cost3 = df_final_sorted3[df_final_sorted3["Warehouse"] == "TOTAL'
total_optimized_cost3 = df_final_sorted3[df_final_sorted3["Warehouse"] == "TOT/

total_cost_reduction3 = total_initial_cost3 - total_optimized_cost3
cost_reduction_percentage3 = (total_cost_reduction3 / total_initial_cost) * 10(

# Print the results
print(f"\n💰 Total Cost Reduction: {total_cost_reduction3:.2f}")
print(f"📉 Cost Reduction Percentage: {cost_reduction_percentage3:.2f}%")
```

```
💰 Total Cost Reduction: 37.66
📉 Cost Reduction Percentage: 3.08%
```

OVERALL COST ANALYSIS

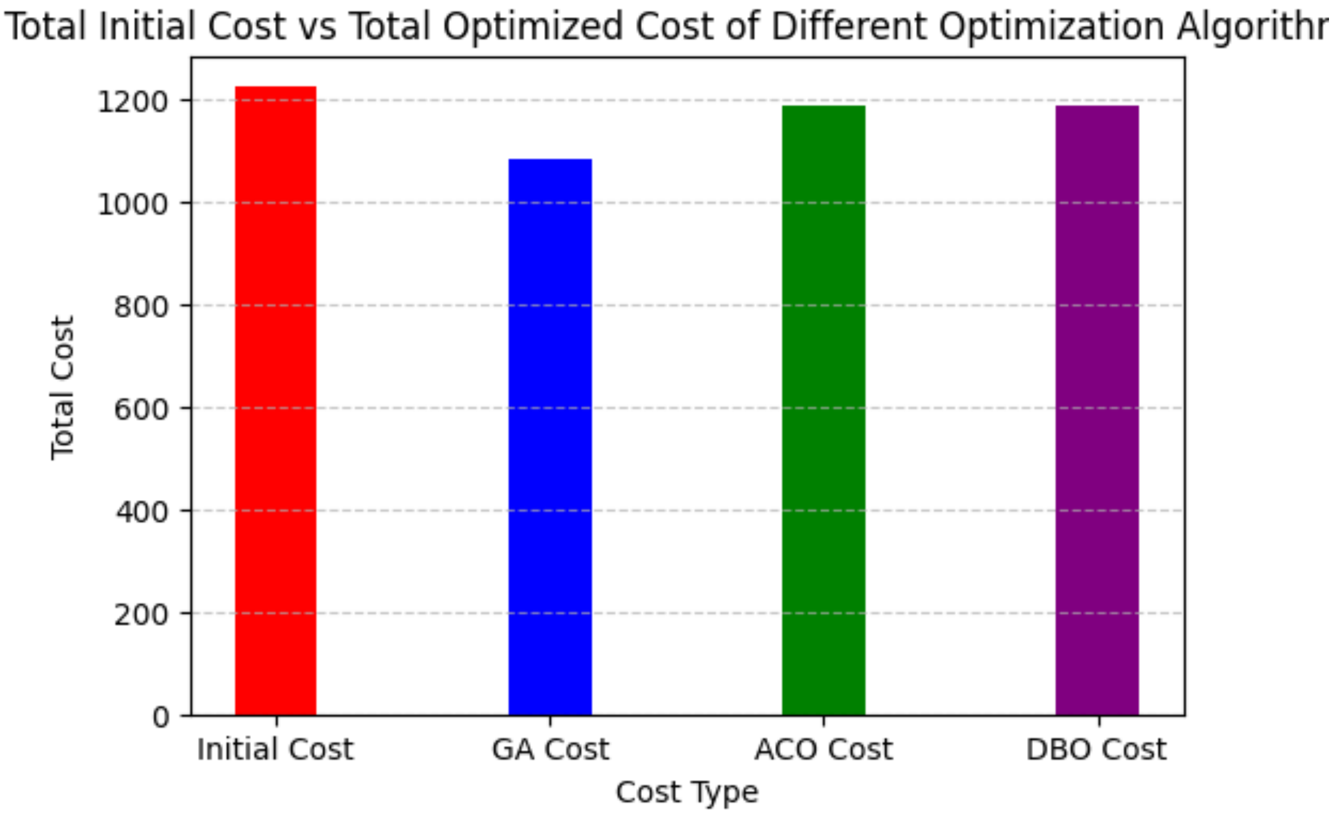
```
import matplotlib.pyplot as plt
import numpy as np

# Ensure all dataframes exclude the "TOTAL" row
df_filtered1 = df_final_sorted1[df_final_sorted1["Warehouse"] != "TOTAL"]
df_filtered2 = df_final_sorted2[df_final_sorted2["Warehouse"] != "TOTAL"]
df_filtered3 = df_final_sorted3[df_final_sorted3["Warehouse"] != "TOTAL"]

# Set width of bars
bar_width = 0.2
x_indexes = np.arange(len(df_filtered1["Warehouse"]))

# Create the grouped bar chart
plt.figure(figsize=(16, 7))
plt.bar(x_indexes - (1.5 * bar_width), df_filtered1["Initial Cost"], width=bar_w
plt.bar(x_indexes - (0.5 * bar_width), df_filtered1["Optimized Cost"], width=bar
plt.bar(x_indexes + (0.5 * bar_width), df_filtered2["Optimized Cost"], width=bar
plt.bar(x_indexes + (1.5 * bar_width), df_filtered3["Optimized Cost"], width=bar

# Add labels and title
plt.xlabel("Warehouse")
plt.ylabel("Cost")
plt.title("Comparison of Initial Cost vs Optimized Costs using Different Algorit
plt.xticks(ticks=x_indexes, labels=df_filtered1["Warehouse"], rotation=90)
plt.legend()
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
```

```
plt.show()
```



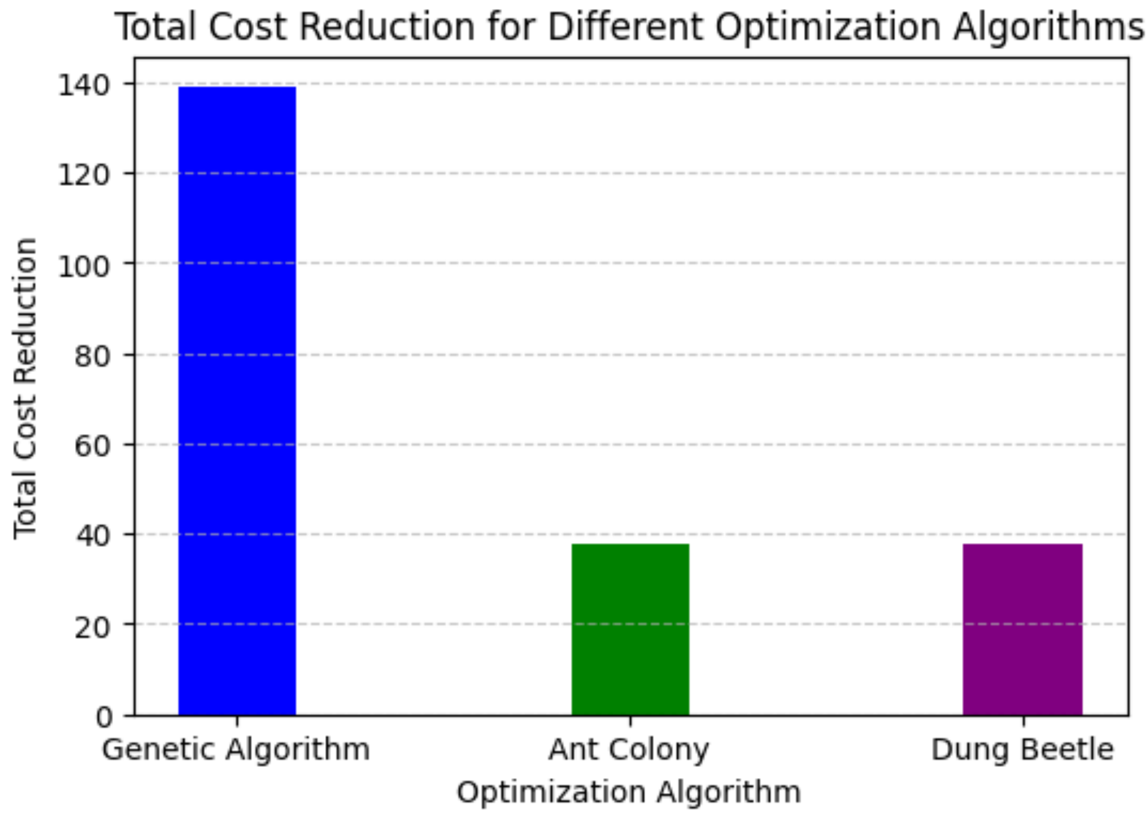

```
import matplotlib.pyplot as plt
import numpy as np

# Extract total cost values from the "TOTAL" row for each optimization algorith
total_initial_cost = df_final_sorted1[df_final_sorted1["Warehouse"] == "TOTAL"]
optimized_cost_genetic = df_final_sorted1[df_final_sorted1["Warehouse"] == "TOT
optimized_cost_ant_colony = df_final_sorted2[df_final_sorted2["Warehouse"] == '
optimized_cost_dung_beetle = df_final_sorted3[df_final_sorted3["Warehouse"] ==
```

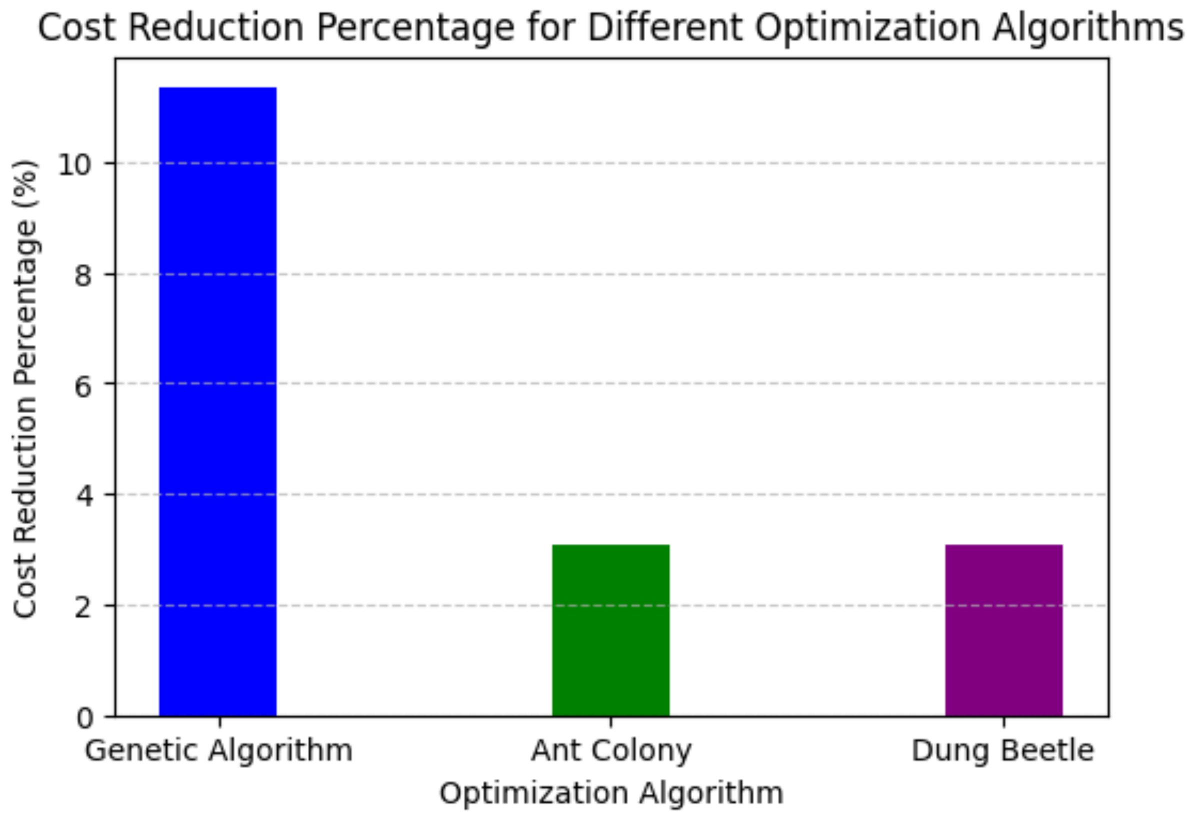
```
# Define labels and values
labels = ["Initial Cost", "GA Cost", "ACO Cost", "DBO Cost"]
values = [total_initial_cost, optimized_cost_genetic, optimized_cost_ant_colony
colors = ["red", "blue", "green", "purple"]

# Create bar chart
plt.figure(figsize=(6, 4))
plt.bar(labels, values, color=colors, width=0.3)

# Add labels and title
plt.xlabel("Cost Type")
plt.ylabel("Total Cost")
plt.title("Total Initial Cost vs Total Optimized Cost of Different Optimization
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
plt.show()
```




```
import matplotlib.pyplot as plt
import numpy as np

# Define the labels for the algorithms
labels = ["Genetic Algorithm", "Ant Colony", "Dung Beetle"]
```

```
# Define the total cost reduction values
total_cost_reduction_values = [total_cost_reduction1, total_cost_reduction2, tot

# Define the cost reduction percentage values
cost_reduction_percentage_values = [cost_reduction_percentage1, cost_reduction_p

# Set width of bars
bar_width = 0.3

# Create figure for Total Cost Reduction
plt.figure(figsize=(6, 4))
plt.bar(labels, total_cost_reduction_values, color=['blue', 'green', 'purple'],

# Add labels and title
plt.xlabel("Optimization Algorithm")
plt.ylabel("Total Cost Reduction")
plt.title("Total Cost Reduction for Different Optimization Algorithms")
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
plt.show()

# Create figure for Cost Reduction Percentage
plt.figure(figsize=(6, 4))
plt.bar(labels, cost_reduction_percentage_values, color=['blue', 'green', 'purpl

# Add labels and title
plt.xlabel("Optimization Algorithm")
plt.ylabel("Cost Reduction Percentage (%)")
plt.title("Cost Reduction Percentage for Different Optimization Algorithms")
plt.grid(axis='y', linestyle='--', alpha=0.7)

# Show plot
plt.show()
```


Total Cost Reduction for Different Optimization Algorithms
Total Cost Reduction
0
20
40
60
80
100
120
140
Genetic Algorithm
Ant Colony
Dung Beetle
Optimization Algorithm


Cost Reduction Percentage for Different Optimization Algorithms
Cost Reduction Percentage (%)
0
2
4
6
8
10
Genetic Algorithm
Ant Colony
Dung Beetle
Optimization Algorithm