Supply Chain Analysis

Redefine the Supply Chain Network for the next 5 years considering the recent increase in shipping costs and the forecasts of future demand.

In [1]:
```
import pandas as pd
!pip install pulp
from pulp import *
import seaborn as sns
import matplotlib.pyplot as plt
```

```
Requirement already satisfied: pulp in c:\users\mani ganesh\anaconda3\lib\site-packages (2.7.0)
```

Plant Location

Manufacturing variable costs

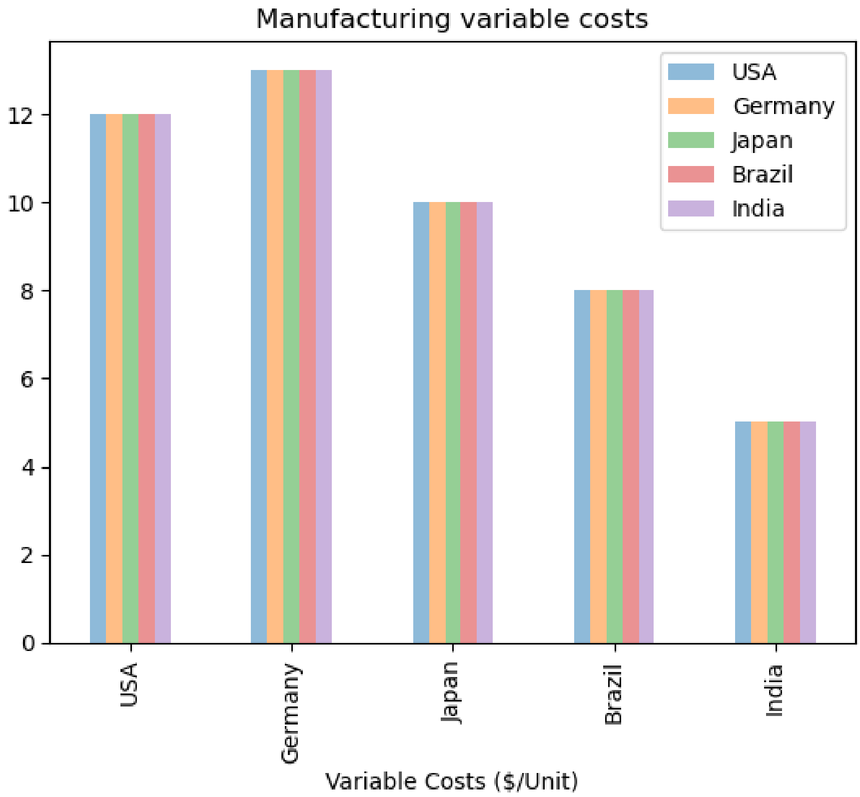
In [2]:
```
# Import Costs
manvar_costs = pd.read_excel(r"C:\Users\mani ganesh\Downloads\Supply Chain Optimization\variable_co
manvar_costs
```

Out[2]:

Variable Costs ($/Unit)	USA	Germany	Japan	Brazil	India
USA	12	12	12	12	12
Germany	13	13	13	13	13
Japan	10	10	10	10	10
Brazil	8	8	8	8	8
India	5	5	5	5	5

In [3]:
```
manvar_costs.plot(kind="bar", title="Manufacturing variable costs", alpha = 0.5)
```

Out[3]:
```
<Axes: title={'center': 'Manufacturing variable costs'}, xlabel='Variable Costs ($/Unit)'>
```



India has the lowest manufacturing variable cost per unit, while Germany and the USA have relatively higher manufacturing variable costs compared to the other countries.

Freight Costs

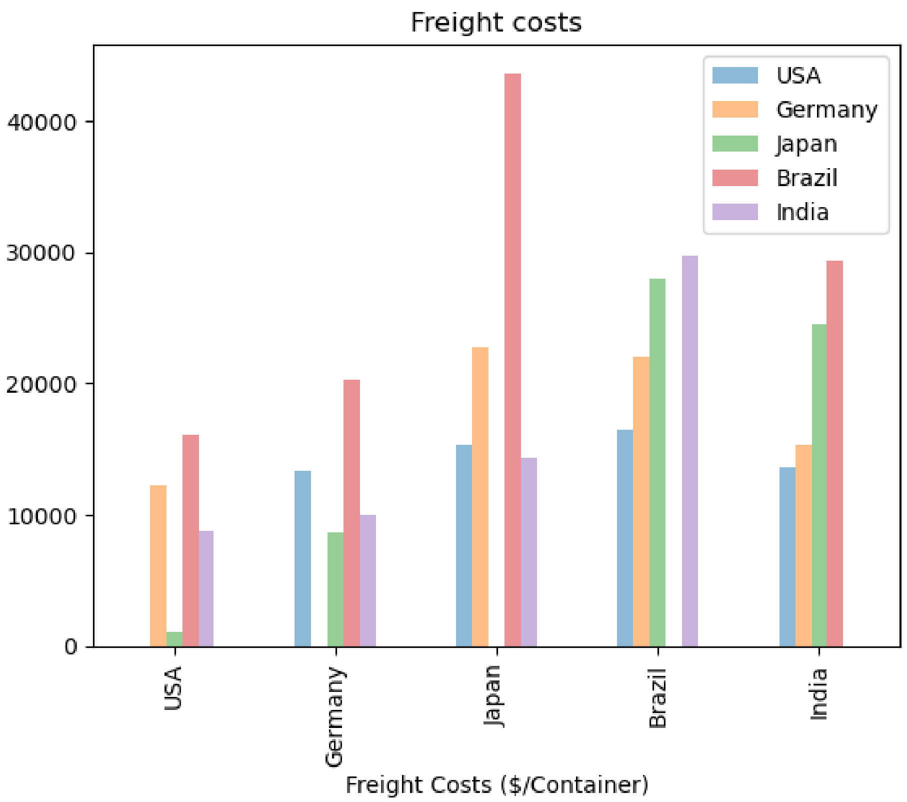
In [4]:
```python
# Import Costs
freight_costs = pd.read_excel(r"C:\Users\mani ganesh\Downloads\Supply Chain Optimization\freight_co
freight_costs
```

Out[4]:

Freight Costs ($/Container)	USA	Germany	Japan	Brazil	India
USA	0	12250	1100	16100	8778
Germany	13335	0	8617	20244	10073
Japan	15400	22750	0	43610	14350
Brazil	16450	22050	28000	0	29750
India	13650	15400	24500	29400	0

In [30]:
```python
freight_costs.plot(kind="bar", title="Freight costs", alpha = 0.5)
```

Out[30]:
```
<Axes: title={'center': 'Freight costs'}, xlabel='Freight Costs ($/Container)'>
```



Shipping containers from Japan to the USA incurs a cost of $15, 400 percontainer, significantlyhigherthanthecostof$ 1,100 when transporting containers from the USA to Japan.

Additionally, the cost of shipping containers from Japan to Brazil is the highest among all routes, amounting to $43,610 per container.

These cost disparities highlight varying transportation expenses based on the shipping routes between different countries within the supply chain network.

Variable Costs

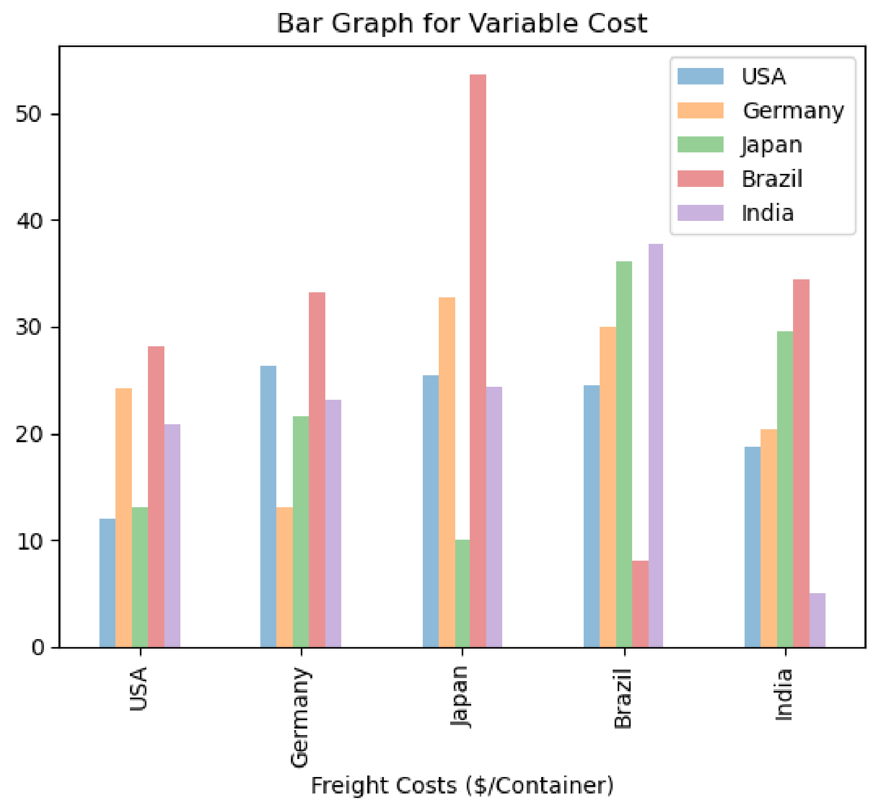
In [6]:
```python
# Variable Costs
var_cost = freight_costs/1000 + manvar_costs
var_cost
```

Out[6]:

Freight Costs ($/Container)	USA	Germany	Japan	Brazil	India
USA	12.000	24.25	13.100	28.100	20.778
Germany	26.335	13.00	21.617	33.244	23.073
Japan	25.400	32.75	10.000	53.610	24.350
Brazil	24.450	30.05	36.000	8.000	37.750
India	18.650	20.40	29.500	34.400	5.000

In [7]:
```python
var_cost.plot(kind="bar", title="Bar Graph for Variable Cost", alpha = 0.5)
```

Out[7]:
```
<Axes: title={'center': 'Bar Graph for Variable Cost'}, xlabel='Freight Costs ($/Container)'>
```



Fixed Costs

These ranges depict the variability in fixed costs among different countries, showcasing the potential range within which fixed expenses might fall for each specific country in the supply chain network.

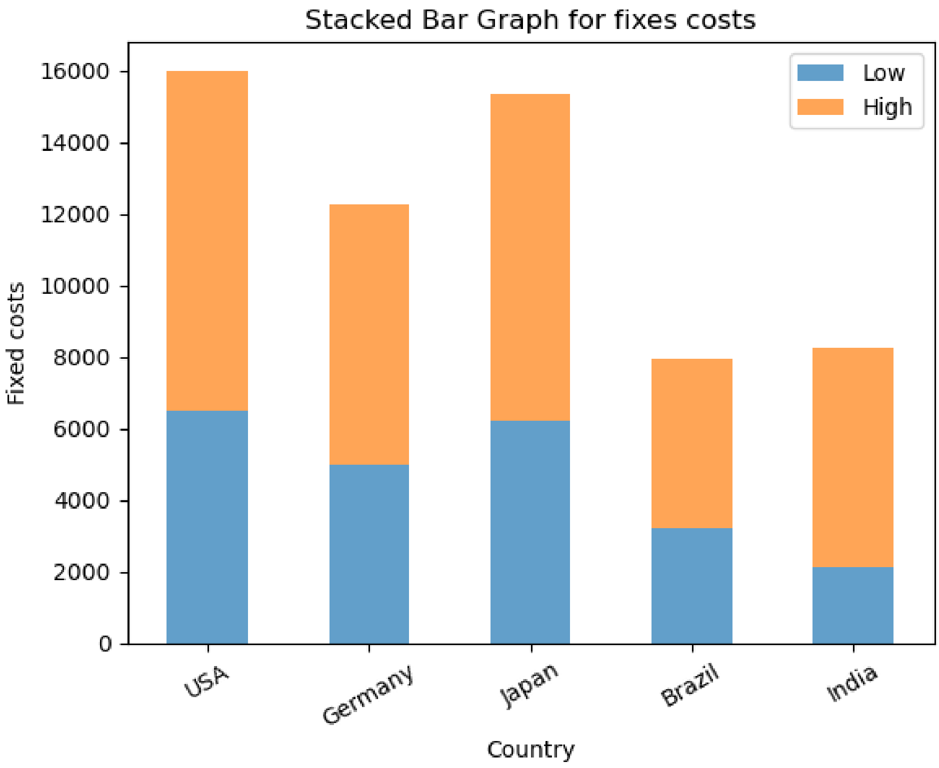
In [8]:
```python
# Import Costs
fixed_costs = pd.read_excel(r"C:\Users\mani ganesh\Downloads\Supply Chain Optimization\fixed_cost.x
fixed_costs
```

Out[8]:

	Low	High
USA	6500	9500
Germany	4980	7270
Japan	6230	9100
Brazil	3230	4730
India	2110	6160

In [9]:
```
# Create the stacked bar graph
alpha = 0.7
fixed_costs.plot(kind="bar", stacked=True, title="Stacked Bar Graph for fixes costs", alpha = alpha
plt.xticks(rotation=30)
plt.xlabel("Country")
plt.ylabel("Fixed costs")
```

Out[9]:
```
Text(0, 0.5, 'Fixed costs')
```



Plants Capacity

These ranges depict the potential production capacity limits for each country within the supply chain network, showing the variability in the monthly production capabilities across different regions.

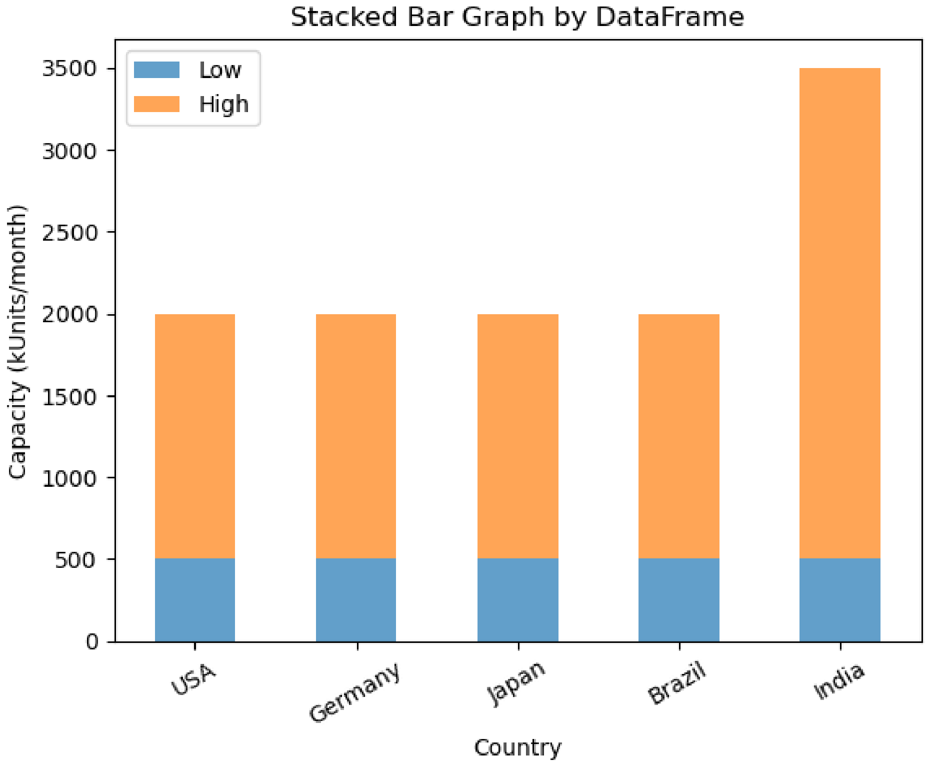
In [10]:
```
# Two types of plants: Low Capacity and High Capacity Plant
cap = pd.read_excel(r"C:\Users\mani ganesh\Downloads\Supply Chain Optimization\capacity.xlsx", inde
cap
```

Out[10]:

	Low	High
Capacity (kUnits/month)		
USA	500	1500
Germany	500	1500
Japan	500	1500
Brazil	500	1500
India	500	3000

In [11]:
```python
# Create the stacked bar graph
alpha = 0.7
cap.plot(kind="bar", stacked=True, title="Stacked Bar Graph by DataFrame", alpha = alpha)
plt.xticks(rotation=30)
plt.xlabel("Country")
plt.ylabel("Capacity (kUnits/month)")
```

Out[11]: Text(0, 0.5, 'Capacity (kUnits/month)')



Demand

These figures represent the quantity of units required per month in each country, indicating the demand levels that need to be fulfilled by the supply chain to meet the market requirements in each region.

In [12]:
```python
#Demand
demand = pd.read_excel(r"C:\Users\mani ganesh\Downloads\Supply Chain Optimization\demand.xlsx", ind
demand
```

Out[12]:

	Unnamed: 1	Unnamed: 2
NaN	(Units/month)	Demand
NaN	USA	2800000
NaN	Germany	90000
NaN	Japan	1700000
NaN	Brazil	145000
NaN	India	160000

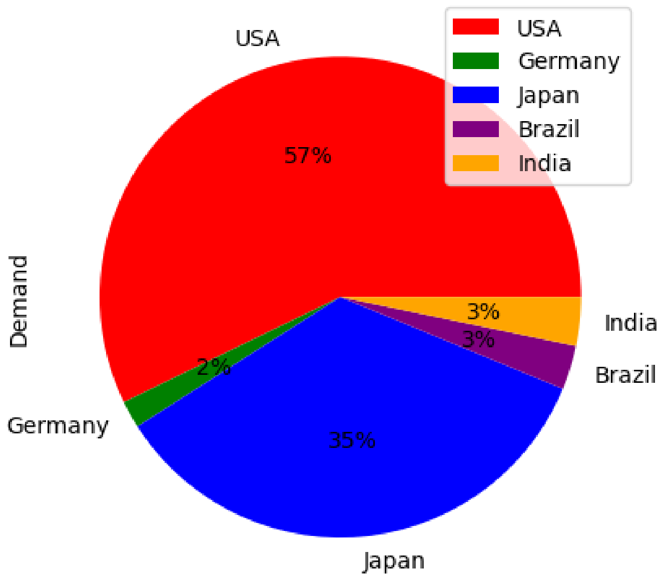
In [13]:
```
demand.rename(columns={"Unnamed: 1": "(Units/month)", "Unnamed: 2": "Demand"}, inplace=True)
demand = demand.tail(-1)
demand = demand.reset_index(drop=True)
demand.set_index('(Units/month)', inplace=True)
demand
```

Out[13]:

	Demand
(Units/month)	
USA	2800000
Germany	90000
Japan	1700000
Brazil	145000
India	160000

In [14]:
```
colors = ['red', 'green', 'blue', 'purple', 'orange']
demand.plot( kind='pie',y='Demand', autopct='%1.0f%%', colors=colors)
```

Out[14]: <Axes: ylabel='Demand'>



US market is driving more than half of the demand.

Decision Variables

In [15]:
```
# Define Decision Variables
loc = ['USA', 'Germany', 'Japan', 'Brazil', 'India']
size = ['Low', 'High']
```

In [16]:
```
# Initialize Class
model = LpProblem("Capacitated_Plant_Location_Model", LpMinimize)
```

In [17]:
```
# Create Decision Variables
x = LpVariable.dicts("production_",
                     [(i,j) for i in loc
                      for j in loc],
                     lowBound=0, upBound=None, cat='continuous') #Variables that can take only real
x
```

Out[17]:
```
{('USA', 'USA'): production__('USA',_'USA'),
 ('USA', 'Germany'): production__('USA',_'Germany'),
 ('USA', 'Japan'): production__('USA',_'Japan'),
 ('USA', 'Brazil'): production__('USA',_'Brazil'),
 ('USA', 'India'): production__('USA',_'India'),
 ('Germany', 'USA'): production__('Germany',_'USA'),
 ('Germany', 'Germany'): production__('Germany',_'Germany'),
 ('Germany', 'Japan'): production__('Germany',_'Japan'),
 ('Germany', 'Brazil'): production__('Germany',_'Brazil'),
 ('Germany', 'India'): production__('Germany',_'India'),
 ('Japan', 'USA'): production__('Japan',_'USA'),
 ('Japan', 'Germany'): production__('Japan',_'Germany'),
 ('Japan', 'Japan'): production__('Japan',_'Japan'),
 ('Japan', 'Brazil'): production__('Japan',_'Brazil'),
 ('Japan', 'India'): production__('Japan',_'India'),
 ('Brazil', 'USA'): production__('Brazil',_'USA'),
 ('Brazil', 'Germany'): production__('Brazil',_'Germany'),
 ('Brazil', 'Japan'): production__('Brazil',_'Japan'),
 ('Brazil', 'Brazil'): production__('Brazil',_'Brazil'),
 ('Brazil', 'India'): production__('Brazil',_'India'),
 ('India', 'USA'): production__('India',_'USA'),
 ('India', 'Germany'): production__('India',_'Germany'),
 ('India', 'Japan'): production__('India',_'Japan'),
 ('India', 'Brazil'): production__('India',_'Brazil'),
 ('India', 'India'): production__('India',_'India')}
```

In [18]:
```
y = LpVariable.dicts("plant_",
                     [(i,s) for s in size
                      for i in loc],
                     cat='Binary') # they can take only two values (0 or 1)
y
```

Out[18]:
```
{('USA', 'Low'): plant__('USA',_'Low'),
 ('Germany', 'Low'): plant__('Germany',_'Low'),
 ('Japan', 'Low'): plant__('Japan',_'Low'),
 ('Brazil', 'Low'): plant__('Brazil',_'Low'),
 ('India', 'Low'): plant__('India',_'Low'),
 ('USA', 'High'): plant__('USA',_'High'),
 ('Germany', 'High'): plant__('Germany',_'High'),
 ('Japan', 'High'): plant__('Japan',_'High'),
 ('Brazil', 'High'): plant__('Brazil',_'High'),
 ('India', 'High'): plant__('India',_'High')}
```

In [19]:
```
# Define Objective Function
model += (lpSum([fixed_costs.loc[i,s] * y[(i,s)] * 1000 for s in size for i in loc])
          + lpSum([var_cost.loc[i,j] * x[(i,j)]   for i in loc for j in loc]))
```

In [20]:
```
# Add Constraints
# Constraints 1 Supply meets the demant in market.
for j in loc:
    model += lpSum([x[(i, j)] for i in loc]) == demand.loc[j,'Demand']

# Constraint 2 Maximum production capacity per plant
for i in loc:
    model += lpSum([x[(i, j)] for j in loc]) <= lpSum([cap.loc[i,s]*y[(i,s)] * 1000
                                                       for s in size])
```

In [21]:
```python
# Solve Model
model.solve()
print("Total Costs = {:,} ($/Month)".format(int(value(model.objective))))
print('\n' + "Status: {}".format(LpStatus[model.status]))
```

```
Total Costs = 92,981,000 ($/Month)

Status: Optimal
```

In [22]:
```python
# Dictionnary
dict_plant = {}
dict_prod = {}
for v in model.variables():
    if 'plant' in v.name:
        name = v.name.replace('plant__', '').replace('_', '')
        dict_plant[name] = int(v.varValue)
        p_name = name
    else:
        name = v.name.replace('production__', '').replace('_', '')
        dict_prod[name] = v.varValue
    print(name, "=", v.varValue)
```

```
('Brazil','High') = 0.0
('Brazil','Low') = 1.0
('Germany','High') = 0.0
('Germany','Low') = 0.0
('India','High') = 1.0
('India','Low') = 0.0
('Japan','High') = 1.0
('Japan','Low') = 0.0
('USA','High') = 1.0
('USA','Low') = 0.0
('Brazil','Brazil') = 145000.0
('Brazil','Germany') = 0.0
('Brazil','India') = 0.0
('Brazil','Japan') = 0.0
('Brazil','USA') = 0.0
('Germany','Brazil') = 0.0
('Germany','Germany') = 0.0
('Germany','India') = 0.0
('Germany','Japan') = 0.0
('Germany','USA') = 0.0
```

In [23]:
```python
# Extract data from dictionaries
plant_data = []
prod_data = []
for name, value in dict_plant.items():
    plant_data.append([name, value])
for name, value in dict_prod.items():
    prod_data.append([name, value])

# Create separate DataFrames
df_plant = pd.DataFrame(plant_data, columns=["Plant", "Production"])
df_prod = pd.DataFrame(prod_data, columns=["Product", "Production"])

df_plant
```

Out[23]:

	Plant	Production
0	('Brazil','High')	0
1	('Brazil','Low')	1
2	('Germany','High')	0
3	('Germany','Low')	0
4	('India','High')	1
5	('India','Low')	0
6	('Japan','High')	1
7	('Japan','Low')	0
8	('USA','High')	1
9	('USA','Low')	0

In [31]:
```python
# Capacity Plant
list_low, list_high = [], []
for l in loc:
    for cap in ['Low', 'High']:
        x = "('{}','{}')".format(l, cap)
        if cap == 'Low':
            list_low.append(dict_plant[x])
        else:
            list_high.append(dict_plant[x])
df_capacity = pd.DataFrame({'Location': loc, 'Low': list_low, 'High': list_high}).set_index('Locati

df_capacity
```

Out[31]:

	Low	High
Location		
USA	0	1
Germany	0	0
Japan	0	1
Brazil	1	0
India	0	1

Based on the given data:

- USA plant is in a high-production state.
- Germany plant is not in production (zero production).
- Japan plant is in a high-production state.
- Brazil plant is in a low-production state.
- India plant is in a high-production state.

These values likely represent the optimized allocation or utilization of plants in a specific scenario, based on the constraints and objectives defined within the linear programming or optimization model implemented using PuLP.