Optimized_supply_chain_network

August 15, 2020

1 Design an optimized supply chain network

Author: Devanshi Verma **Date**: August-15-2020 **Goal**: Determine regional production at a plant such that we have the balance between high capacity and low capacity plants while mainting regional demands and low costs

Modelling

- Production at regional facilities: Low and High
- Production to other regions
- Productional facilities open or close

Decision Variables

$$X_{i,j} = \text{Quantity produced at i and shipped to j}$$

$$\left\{\begin{matrix} Y_{i,s} = 1 & \text{if plant location i and capacity s is open} \\ Y_{i,s} = 0 & \text{if plant location i and capacity s is closed} \end{matrix}\right\}$$

Objective Function

$$min \sum_{i=1}^{n} f_{is}y_{is} + \sum_{i=1}^{n}\sum_{i=1}^{m} v_{ij}x_{ij}$$

- i.e. Sum of (fixed costs * Yis) over production facilities + Sum of (variablecost X xij) over productional facilities and number of markets

Constraints

$$\sum_{i=1}^{n} x_{ij} = D_j$$

- Where j=1 to m and D=demand - n= production facilities - m= markets

$$Y_{ih} + Y_{il} <= 1$$

- h= high capacity - l=low capacity

$$\sum_{i=1}^{n} x_{ij} <= \sum_{i=1}^{n} K_{is}y_{is}$$

- K= Potiential Capacity

Type of Optimization problem: Mixed Integer programming since X is continous whereas Y is constrained to integer values.

- More on the problem can be found at :http://web.mit.edu/15.053/www/AMP-Chapter-09.pdf

```python
[38]: #importing the libraries
      import pandas as pd
      from pulp import *
```

```python
[39]: #importing the datasets
      demand=pd.read_csv("Data/Demand.csv")
      fix_cost=pd.read_csv("Data/fix_cost.csv")
      var_cost=pd.read_csv("Data/var_cost.csv")
      cap=pd.read_csv("Data/cap.csv")
```

```python
[40]: #Setting indexes
      fix_cost=fix_cost.set_index("Supply_Region")
      var_cost=var_cost.set_index("Supply_Region")
      demand=demand.set_index("Supply_Region")
      cap=cap.set_index("Supply_Region")
```

Datasets

```python
[41]: fix_cost.head()
```

```
[41]:                Low_Cap  High_Cap
      Supply_Region
      U.S               6500      9500
      Brazil            3230      4730
      Canada            4980      7270
      Mexico            1000      1460
      Argentina         1200      1752
```

```python
[42]: demand.head()
```

```
[42]:               Dmd
      Supply_Region
      U.S          3653
      Brazil        700
      Canada       2587
      Mexico        652
      Argentina    1093
```

```python
[43]: var_cost.head()
```

```
[43]:               U.S   Brazil   Canada   Mexico   Argentina   Chile   Colombia  \
      Supply_Region
      U.S           0.6      7.0      2.3      1.9         4.0     3.2        4.1
```

```
Brazil       7.0     0.6     9.2     7.0        2.8     1.5        3.2
Canada       2.3     9.2     0.6     3.6       11.2     5.3        6.4
Mexico       1.9     7.0     3.6     0.7        7.4     3.7        3.7
Argentina    4.0     2.8    11.2     7.4        0.5     0.6        7.0
```

```
              Puerto Rico  Uruguay
Supply_Region
U.S                   3.5     4.60
Brazil                4.0     1.00
Canada                5.4     5.50
Mexico                3.7     4.00
Argentina             6.3     0.65
```

[44]: `cap.head()`

[44]:
```
              Low_Cap  High_Cap
Supply_Region
U.S             500.0      1500
Brazil          500.0      1500
Canada          500.0      1500
Mexico          500.0      1500
Argentina       500.0      1500
```

Model

[50]:
```python
#Initialise the model
model=LpProblem("Capacitedplantlocation",LpMinimize)

#Decision Variables
loc=list(demand.index)
size=['Low_Cap','High_Cap']

x=LpVariable.dicts("production_", [(i,j) for i in loc for j in
 loc],lowBound=0,upBound=None,cat='Continuous')
y=LpVariable.dicts("plant_", [(i,s) for i in loc for s in size],cat='Binary')

#Objective Function
model += (lpSum([fix_cost.loc[i,s] * y[(i,s)] 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]))

# Define the constraints
for j in loc:
    model += lpSum([x[i,j] for i in loc]) == demand.loc[j,'Dmd']

for i in loc:
    model += lpSum([x[(i, j)] for j in loc]) <= lpSum([cap.loc[i,s] * y[i,s]
 for s in size])
```

3

```
for i in loc:
    model +=  y[i,'High_Cap']+ y[i,'Low_Cap'] <= 1

model
```

[50]: Capacitedplantlocation:
MINIMIZE
1752*plant__('Argentina',_'High_Cap') + 1200*plant__('Argentina',_'Low_Cap') +
4730*plant__('Brazil',_'High_Cap') + 3230*plant__('Brazil',_'Low_Cap') +
7270*plant__('Canada',_'High_Cap') + 4980*plant__('Canada',_'Low_Cap') +
2336*plant__('Chile',_'High_Cap') + 1600*plant__('Chile',_'Low_Cap') +
1460*plant__('Colombia',_'High_Cap') + 1000*plant__('Colombia',_'Low_Cap') +
1460*plant__('Mexico',_'High_Cap') + 1000*plant__('Mexico',_'Low_Cap') +
4672*plant__('Puerto_Rico',_'High_Cap') + 3200*plant__('Puerto_Rico',_'Low_Cap')
+ 9500*plant__('U.S',_'High_Cap') + 6500*plant__('U.S',_'Low_Cap') +
2482*plant__('Uruguay',_'High_Cap') + 1700*plant__('Uruguay',_'Low_Cap') +
0.5*production__('Argentina',_'Argentina') +
2.8*production__('Argentina',_'Brazil') +
11.2*production__('Argentina',_'Canada') +
0.6*production__('Argentina',_'Chile') +
7.0*production__('Argentina',_'Colombia') +
7.4*production__('Argentina',_'Mexico') +
6.3*production__('Argentina',_'Puerto_Rico') +
4.0*production__('Argentina',_'U.S') + 0.65*production__('Argentina',_'Uruguay')
+ 2.8*production__('Brazil',_'Argentina') + 0.6*production__('Brazil',_'Brazil')
+ 9.2*production__('Brazil',_'Canada') + 1.5*production__('Brazil',_'Chile') +
3.2*production__('Brazil',_'Colombia') + 7.0*production__('Brazil',_'Mexico') +
4.0*production__('Brazil',_'Puerto_Rico') + 7.0*production__('Brazil',_'U.S') +
1.0*production__('Brazil',_'Uruguay') + 11.2*production__('Canada',_'Argentina')
+ 9.2*production__('Canada',_'Brazil') + 0.6*production__('Canada',_'Canada') +
5.3*production__('Canada',_'Chile') + 6.4*production__('Canada',_'Colombia') +
3.6*production__('Canada',_'Mexico') + 5.4*production__('Canada',_'Puerto_Rico')
+ 2.3*production__('Canada',_'U.S') + 5.5*production__('Canada',_'Uruguay') +
0.6*production__('Chile',_'Argentina') + 1.5*production__('Chile',_'Brazil') +
5.3*production__('Chile',_'Canada') + 0.3*production__('Chile',_'Chile') +
3.2*production__('Chile',_'Colombia') + 3.7*production__('Chile',_'Mexico') +
3.0*production__('Chile',_'Puerto_Rico') + 3.2*production__('Chile',_'U.S') +
1.0*production__('Chile',_'Uruguay') + 7.0*production__('Colombia',_'Argentina')
+ 3.2*production__('Colombia',_'Brazil') +
6.4*production__('Colombia',_'Canada') + 3.2*production__('Colombia',_'Chile') +
0.28*production__('Colombia',_'Colombia') +
3.7*production__('Colombia',_'Mexico') +
1.7*production__('Colombia',_'Puerto_Rico') +
4.1*production__('Colombia',_'U.S') + 3.5*production__('Colombia',_'Uruguay') +
7.4*production__('Mexico',_'Argentina') + 7.0*production__('Mexico',_'Brazil') +
3.6*production__('Mexico',_'Canada') + 3.7*production__('Mexico',_'Chile') +
```

3.7*production__('Mexico',_'Colombia') + 0.7*production__('Mexico',_'Mexico') +
3.7*production__('Mexico',_'Puerto_Rico') + 1.9*production__('Mexico',_'U.S') +
4.0*production__('Mexico',_'Uruguay') +
6.3*production__('Puerto_Rico',_'Argentina') +
4.0*production__('Puerto_Rico',_'Brazil') +
5.4*production__('Puerto_Rico',_'Canada') +
3.0*production__('Puerto_Rico',_'Chile') +
1.7*production__('Puerto_Rico',_'Colombia') +
3.7*production__('Puerto_Rico',_'Mexico') +
0.5*production__('Puerto_Rico',_'Puerto_Rico') +
3.5*production__('Puerto_Rico',_'U.S') +
2.9*production__('Puerto_Rico',_'Uruguay') +
4.0*production__('U.S',_'Argentina') + 7.0*production__('U.S',_'Brazil') +
2.3*production__('U.S',_'Canada') + 3.2*production__('U.S',_'Chile') +
4.1*production__('U.S',_'Colombia') + 1.9*production__('U.S',_'Mexico') +
3.5*production__('U.S',_'Puerto_Rico') + 0.6*production__('U.S',_'U.S') +
4.6*production__('U.S',_'Uruguay') + 0.65*production__('Uruguay',_'Argentina') +
1.0*production__('Uruguay',_'Brazil') + 5.5*production__('Uruguay',_'Canada') +
1.0*production__('Uruguay',_'Chile') + 3.5*production__('Uruguay',_'Colombia') +
4.0*production__('Uruguay',_'Mexico') +
2.9*production__('Uruguay',_'Puerto_Rico') + 4.6*production__('Uruguay',_'U.S')
+ 0.3*production__('Uruguay',_'Uruguay') + 0.0
SUBJECT TO
_C1: production__('Argentina',_'U.S') + production__('Brazil',_'U.S')
 + production__('Canada',_'U.S') + production__('Chile',_'U.S')
 + production__('Colombia',_'U.S') + production__('Mexico',_'U.S')
 + production__('Puerto_Rico',_'U.S') + production__('U.S',_'U.S')
 + production__('Uruguay',_'U.S') = 3653

_C2: production__('Argentina',_'Brazil') + production__('Brazil',_'Brazil')
 + production__('Canada',_'Brazil') + production__('Chile',_'Brazil')
 + production__('Colombia',_'Brazil') + production__('Mexico',_'Brazil')
 + production__('Puerto_Rico',_'Brazil') + production__('U.S',_'Brazil')
 + production__('Uruguay',_'Brazil') = 700

_C3: production__('Argentina',_'Canada') + production__('Brazil',_'Canada')
 + production__('Canada',_'Canada') + production__('Chile',_'Canada')
 + production__('Colombia',_'Canada') + production__('Mexico',_'Canada')
 + production__('Puerto_Rico',_'Canada') + production__('U.S',_'Canada')
 + production__('Uruguay',_'Canada') = 2587

_C4: production__('Argentina',_'Mexico') + production__('Brazil',_'Mexico')
 + production__('Canada',_'Mexico') + production__('Chile',_'Mexico')
 + production__('Colombia',_'Mexico') + production__('Mexico',_'Mexico')
 + production__('Puerto_Rico',_'Mexico') + production__('U.S',_'Mexico')
 + production__('Uruguay',_'Mexico') = 652

```
_C5: production__('Argentina',_'Argentina')
 + production__('Brazil',_'Argentina') + production__('Canada',_'Argentina')
 + production__('Chile',_'Argentina') + production__('Colombia',_'Argentina')
 + production__('Mexico',_'Argentina')
 + production__('Puerto_Rico',_'Argentina') + production__('U.S',_'Argentina')
 + production__('Uruguay',_'Argentina') = 1093

_C6: production__('Argentina',_'Chile') + production__('Brazil',_'Chile')
 + production__('Canada',_'Chile') + production__('Chile',_'Chile')
 + production__('Colombia',_'Chile') + production__('Mexico',_'Chile')
 + production__('Puerto_Rico',_'Chile') + production__('U.S',_'Chile')
 + production__('Uruguay',_'Chile') = 262

_C7: production__('Argentina',_'Colombia')
 + production__('Brazil',_'Colombia') + production__('Canada',_'Colombia')
 + production__('Chile',_'Colombia') + production__('Colombia',_'Colombia')
 + production__('Mexico',_'Colombia')
 + production__('Puerto_Rico',_'Colombia') + production__('U.S',_'Colombia')
 + production__('Uruguay',_'Colombia') = 902

_C8: production__('Argentina',_'Puerto_Rico')
 + production__('Brazil',_'Puerto_Rico')
 + production__('Canada',_'Puerto_Rico')
 + production__('Chile',_'Puerto_Rico')
 + production__('Colombia',_'Puerto_Rico')
 + production__('Mexico',_'Puerto_Rico')
 + production__('Puerto_Rico',_'Puerto_Rico')
 + production__('U.S',_'Puerto_Rico') + production__('Uruguay',_'Puerto_Rico')
 = 11

_C9: production__('Argentina',_'Uruguay') + production__('Brazil',_'Uruguay')
 + production__('Canada',_'Uruguay') + production__('Chile',_'Uruguay')
 + production__('Colombia',_'Uruguay') + production__('Mexico',_'Uruguay')
 + production__('Puerto_Rico',_'Uruguay') + production__('U.S',_'Uruguay')
 + production__('Uruguay',_'Uruguay') = 9

_C10: - 1500 plant__('U.S',_'High_Cap') - 500 plant__('U.S',_'Low_Cap')
 + production__('U.S',_'Argentina') + production__('U.S',_'Brazil')
 + production__('U.S',_'Canada') + production__('U.S',_'Chile')
 + production__('U.S',_'Colombia') + production__('U.S',_'Mexico')
 + production__('U.S',_'Puerto_Rico') + production__('U.S',_'U.S')
 + production__('U.S',_'Uruguay') <= 0

_C11: - 1500 plant__('Brazil',_'High_Cap') - 500 plant__('Brazil',_'Low_Cap')
 + production__('Brazil',_'Argentina') + production__('Brazil',_'Brazil')
 + production__('Brazil',_'Canada') + production__('Brazil',_'Chile')
 + production__('Brazil',_'Colombia') + production__('Brazil',_'Mexico')
```

```
+ production__('Brazil',_'Puerto_Rico') + production__('Brazil',_'U.S')
+ production__('Brazil',_'Uruguay') <= 0

_C12: - 1500 plant__('Canada',_'High_Cap') - 500 plant__('Canada',_'Low_Cap')
+ production__('Canada',_'Argentina') + production__('Canada',_'Brazil')
+ production__('Canada',_'Canada') + production__('Canada',_'Chile')
+ production__('Canada',_'Colombia') + production__('Canada',_'Mexico')
+ production__('Canada',_'Puerto_Rico') + production__('Canada',_'U.S')
+ production__('Canada',_'Uruguay') <= 0

_C13: - 1500 plant__('Mexico',_'High_Cap') - 500 plant__('Mexico',_'Low_Cap')
+ production__('Mexico',_'Argentina') + production__('Mexico',_'Brazil')
+ production__('Mexico',_'Canada') + production__('Mexico',_'Chile')
+ production__('Mexico',_'Colombia') + production__('Mexico',_'Mexico')
+ production__('Mexico',_'Puerto_Rico') + production__('Mexico',_'U.S')
+ production__('Mexico',_'Uruguay') <= 0

_C14: - 1500 plant__('Argentina',_'High_Cap')
 - 500 plant__('Argentina',_'Low_Cap')
+ production__('Argentina',_'Argentina')
+ production__('Argentina',_'Brazil') + production__('Argentina',_'Canada')
+ production__('Argentina',_'Chile') + production__('Argentina',_'Colombia')
+ production__('Argentina',_'Mexico')
+ production__('Argentina',_'Puerto_Rico') + production__('Argentina',_'U.S')
+ production__('Argentina',_'Uruguay') <= 0

_C15: - 1500 plant__('Chile',_'High_Cap') - 500 plant__('Chile',_'Low_Cap')
+ production__('Chile',_'Argentina') + production__('Chile',_'Brazil')
+ production__('Chile',_'Canada') + production__('Chile',_'Chile')
+ production__('Chile',_'Colombia') + production__('Chile',_'Mexico')
+ production__('Chile',_'Puerto_Rico') + production__('Chile',_'U.S')
+ production__('Chile',_'Uruguay') <= 0

_C16: - 1500 plant__('Colombia',_'High_Cap')
 - 500 plant__('Colombia',_'Low_Cap') + production__('Colombia',_'Argentina')
+ production__('Colombia',_'Brazil') + production__('Colombia',_'Canada')
+ production__('Colombia',_'Chile') + production__('Colombia',_'Colombia')
+ production__('Colombia',_'Mexico')
+ production__('Colombia',_'Puerto_Rico') + production__('Colombia',_'U.S')
+ production__('Colombia',_'Uruguay') <= 0

_C17: - 1500 plant__('Puerto_Rico',_'High_Cap')
 - 500 plant__('Puerto_Rico',_'Low_Cap')
+ production__('Puerto_Rico',_'Argentina')
+ production__('Puerto_Rico',_'Brazil')
+ production__('Puerto_Rico',_'Canada')
+ production__('Puerto_Rico',_'Chile')
```

```
 + production__('Puerto_Rico',_'Colombia')
 + production__('Puerto_Rico',_'Mexico')
 + production__('Puerto_Rico',_'Puerto_Rico')
 + production__('Puerto_Rico',_'U.S') + production__('Puerto_Rico',_'Uruguay')
 <= 0


_C18: - 1500 plant__('Uruguay',_'High_Cap')
 - 500 plant__('Uruguay',_'Low_Cap') + production__('Uruguay',_'Argentina')
 + production__('Uruguay',_'Brazil') + production__('Uruguay',_'Canada')
 + production__('Uruguay',_'Chile') + production__('Uruguay',_'Colombia')
 + production__('Uruguay',_'Mexico') + production__('Uruguay',_'Puerto_Rico')
 + production__('Uruguay',_'U.S') + production__('Uruguay',_'Uruguay') <= 0


_C19: plant__('U.S',_'High_Cap') + plant__('U.S',_'Low_Cap') <= 1


_C20: plant__('Brazil',_'High_Cap') + plant__('Brazil',_'Low_Cap') <= 1


_C21: plant__('Canada',_'High_Cap') + plant__('Canada',_'Low_Cap') <= 1


_C22: plant__('Mexico',_'High_Cap') + plant__('Mexico',_'Low_Cap') <= 1


_C23: plant__('Argentina',_'High_Cap') + plant__('Argentina',_'Low_Cap') <= 1


_C24: plant__('Chile',_'High_Cap') + plant__('Chile',_'Low_Cap') <= 1


_C25: plant__('Colombia',_'High_Cap') + plant__('Colombia',_'Low_Cap') <= 1


_C26: plant__('Puerto_Rico',_'High_Cap') + plant__('Puerto_Rico',_'Low_Cap')
 <= 1


_C27: plant__('Uruguay',_'High_Cap') + plant__('Uruguay',_'Low_Cap') <= 1


VARIABLES
0 <= plant__('Argentina',_'High_Cap') <= 1 Integer
0 <= plant__('Argentina',_'Low_Cap') <= 1 Integer
0 <= plant__('Brazil',_'High_Cap') <= 1 Integer
0 <= plant__('Brazil',_'Low_Cap') <= 1 Integer
0 <= plant__('Canada',_'High_Cap') <= 1 Integer
0 <= plant__('Canada',_'Low_Cap') <= 1 Integer
0 <= plant__('Chile',_'High_Cap') <= 1 Integer
0 <= plant__('Chile',_'Low_Cap') <= 1 Integer
0 <= plant__('Colombia',_'High_Cap') <= 1 Integer
0 <= plant__('Colombia',_'Low_Cap') <= 1 Integer
0 <= plant__('Mexico',_'High_Cap') <= 1 Integer
0 <= plant__('Mexico',_'Low_Cap') <= 1 Integer
0 <= plant__('Puerto_Rico',_'High_Cap') <= 1 Integer
0 <= plant__('Puerto_Rico',_'Low_Cap') <= 1 Integer
```

```
0 <= plant__('U.S',_'High_Cap') <= 1 Integer
0 <= plant__('U.S',_'Low_Cap') <= 1 Integer
0 <= plant__('Uruguay',_'High_Cap') <= 1 Integer
0 <= plant__('Uruguay',_'Low_Cap') <= 1 Integer
production__('Argentina',_'Argentina') Continuous
production__('Argentina',_'Brazil') Continuous
production__('Argentina',_'Canada') Continuous
production__('Argentina',_'Chile') Continuous
production__('Argentina',_'Colombia') Continuous
production__('Argentina',_'Mexico') Continuous
production__('Argentina',_'Puerto_Rico') Continuous
production__('Argentina',_'U.S') Continuous
production__('Argentina',_'Uruguay') Continuous
production__('Brazil',_'Argentina') Continuous
production__('Brazil',_'Brazil') Continuous
production__('Brazil',_'Canada') Continuous
production__('Brazil',_'Chile') Continuous
production__('Brazil',_'Colombia') Continuous
production__('Brazil',_'Mexico') Continuous
production__('Brazil',_'Puerto_Rico') Continuous
production__('Brazil',_'U.S') Continuous
production__('Brazil',_'Uruguay') Continuous
production__('Canada',_'Argentina') Continuous
production__('Canada',_'Brazil') Continuous
production__('Canada',_'Canada') Continuous
production__('Canada',_'Chile') Continuous
production__('Canada',_'Colombia') Continuous
production__('Canada',_'Mexico') Continuous
production__('Canada',_'Puerto_Rico') Continuous
production__('Canada',_'U.S') Continuous
production__('Canada',_'Uruguay') Continuous
production__('Chile',_'Argentina') Continuous
production__('Chile',_'Brazil') Continuous
production__('Chile',_'Canada') Continuous
production__('Chile',_'Chile') Continuous
production__('Chile',_'Colombia') Continuous
production__('Chile',_'Mexico') Continuous
production__('Chile',_'Puerto_Rico') Continuous
production__('Chile',_'U.S') Continuous
production__('Chile',_'Uruguay') Continuous
production__('Colombia',_'Argentina') Continuous
production__('Colombia',_'Brazil') Continuous
production__('Colombia',_'Canada') Continuous
production__('Colombia',_'Chile') Continuous
production__('Colombia',_'Colombia') Continuous
production__('Colombia',_'Mexico') Continuous
production__('Colombia',_'Puerto_Rico') Continuous
```

```
production__('Colombia',_'U.S') Continuous
production__('Colombia',_'Uruguay') Continuous
production__('Mexico',_'Argentina') Continuous
production__('Mexico',_'Brazil') Continuous
production__('Mexico',_'Canada') Continuous
production__('Mexico',_'Chile') Continuous
production__('Mexico',_'Colombia') Continuous
production__('Mexico',_'Mexico') Continuous
production__('Mexico',_'Puerto_Rico') Continuous
production__('Mexico',_'U.S') Continuous
production__('Mexico',_'Uruguay') Continuous
production__('Puerto_Rico',_'Argentina') Continuous
production__('Puerto_Rico',_'Brazil') Continuous
production__('Puerto_Rico',_'Canada') Continuous
production__('Puerto_Rico',_'Chile') Continuous
production__('Puerto_Rico',_'Colombia') Continuous
production__('Puerto_Rico',_'Mexico') Continuous
production__('Puerto_Rico',_'Puerto_Rico') Continuous
production__('Puerto_Rico',_'U.S') Continuous
production__('Puerto_Rico',_'Uruguay') Continuous
production__('U.S',_'Argentina') Continuous
production__('U.S',_'Brazil') Continuous
production__('U.S',_'Canada') Continuous
production__('U.S',_'Chile') Continuous
production__('U.S',_'Colombia') Continuous
production__('U.S',_'Mexico') Continuous
production__('U.S',_'Puerto_Rico') Continuous
production__('U.S',_'U.S') Continuous
production__('U.S',_'Uruguay') Continuous
production__('Uruguay',_'Argentina') Continuous
production__('Uruguay',_'Brazil') Continuous
production__('Uruguay',_'Canada') Continuous
production__('Uruguay',_'Chile') Continuous
production__('Uruguay',_'Colombia') Continuous
production__('Uruguay',_'Mexico') Continuous
production__('Uruguay',_'Puerto_Rico') Continuous
production__('Uruguay',_'U.S') Continuous
production__('Uruguay',_'Uruguay') Continuous
```

[51]:
```python
#Solving the model
model.solve()

print("Status of the mode is: {}".format(LpStatus[model.status]))
```

Status of the mode is: Optimal

Output

```
[52]:  import re
       for i in model.variables():
           print(i,i.varValue)
```

plant__('Argentina',_'High_Cap') 1.0
plant__('Argentina',_'Low_Cap') 0.0
plant__('Brazil',_'High_Cap') 0.0
plant__('Brazil',_'Low_Cap') 0.0
plant__('Canada',_'High_Cap') 1.0
plant__('Canada',_'Low_Cap') 0.0
plant__('Chile',_'High_Cap') 1.0
plant__('Chile',_'Low_Cap') 0.0
plant__('Colombia',_'High_Cap') 1.0
plant__('Colombia',_'Low_Cap') 0.0
plant__('Mexico',_'High_Cap') 1.0
plant__('Mexico',_'Low_Cap') 0.0
plant__('Puerto_Rico',_'High_Cap') 1.0
plant__('Puerto_Rico',_'Low_Cap') 0.0
plant__('U.S',_'High_Cap') 0.0
plant__('U.S',_'Low_Cap') 0.0
plant__('Uruguay',_'High_Cap') 1.0
plant__('Uruguay',_'Low_Cap') 0.0
production__('Argentina',_'Argentina') 1093.0
production__('Argentina',_'Brazil') 0.0
production__('Argentina',_'Canada') 0.0
production__('Argentina',_'Chile') 262.0
production__('Argentina',_'Colombia') 0.0
production__('Argentina',_'Mexico') 0.0
production__('Argentina',_'Puerto_Rico') 0.0
production__('Argentina',_'U.S') 112.0
production__('Argentina',_'Uruguay') 0.0
production__('Brazil',_'Argentina') 0.0
production__('Brazil',_'Brazil') 0.0
production__('Brazil',_'Canada') 0.0
production__('Brazil',_'Chile') 0.0
production__('Brazil',_'Colombia') 0.0
production__('Brazil',_'Mexico') 0.0
production__('Brazil',_'Puerto_Rico') 0.0
production__('Brazil',_'U.S') 0.0
production__('Brazil',_'Uruguay') 0.0
production__('Canada',_'Argentina') 0.0
production__('Canada',_'Brazil') 0.0
production__('Canada',_'Canada') 1500.0
production__('Canada',_'Chile') 0.0
production__('Canada',_'Colombia') 0.0
production__('Canada',_'Mexico') 0.0
production__('Canada',_'Puerto_Rico') 0.0

```
production__('Canada',_'U.S') 0.0
production__('Canada',_'Uruguay') 0.0
production__('Chile',_'Argentina') 0.0
production__('Chile',_'Brazil') 0.0
production__('Chile',_'Canada') 0.0
production__('Chile',_'Chile') 0.0
production__('Chile',_'Colombia') 0.0
production__('Chile',_'Mexico') 0.0
production__('Chile',_'Puerto_Rico') 0.0
production__('Chile',_'U.S') 1500.0
production__('Chile',_'Uruguay') 0.0
production__('Colombia',_'Argentina') 0.0
production__('Colombia',_'Brazil') 0.0
production__('Colombia',_'Canada') 0.0
production__('Colombia',_'Chile') 0.0
production__('Colombia',_'Colombia') 902.0
production__('Colombia',_'Mexico') 0.0
production__('Colombia',_'Puerto_Rico') 0.0
production__('Colombia',_'U.S') 0.0
production__('Colombia',_'Uruguay') 0.0
production__('Mexico',_'Argentina') 0.0
production__('Mexico',_'Brazil') 0.0
production__('Mexico',_'Canada') 296.0
production__('Mexico',_'Chile') 0.0
production__('Mexico',_'Colombia') 0.0
production__('Mexico',_'Mexico') 652.0
production__('Mexico',_'Puerto_Rico') 0.0
production__('Mexico',_'U.S') 552.0
production__('Mexico',_'Uruguay') 0.0
production__('Puerto_Rico',_'Argentina') 0.0
production__('Puerto_Rico',_'Brazil') 0.0
production__('Puerto_Rico',_'Canada') 0.0
production__('Puerto_Rico',_'Chile') 0.0
production__('Puerto_Rico',_'Colombia') 0.0
production__('Puerto_Rico',_'Mexico') 0.0
production__('Puerto_Rico',_'Puerto_Rico') 11.0
production__('Puerto_Rico',_'U.S') 1489.0
production__('Puerto_Rico',_'Uruguay') 0.0
production__('U.S',_'Argentina') 0.0
production__('U.S',_'Brazil') 0.0
production__('U.S',_'Canada') 0.0
production__('U.S',_'Chile') 0.0
production__('U.S',_'Colombia') 0.0
production__('U.S',_'Mexico') 0.0
production__('U.S',_'Puerto_Rico') 0.0
production__('U.S',_'U.S') 0.0
production__('U.S',_'Uruguay') 0.0
production__('Uruguay',_'Argentina') 0.0
```

```
production__('Uruguay',_'Brazil') 700.0
production__('Uruguay',_'Canada') 791.0
production__('Uruguay',_'Chile') 0.0
production__('Uruguay',_'Colombia') 0.0
production__('Uruguay',_'Mexico') 0.0
production__('Uruguay',_'Puerto_Rico') 0.0
production__('Uruguay',_'U.S') 0.0
production__('Uruguay',_'Uruguay') 9.0
```

[55]:
```python
#converting the output into a pandas dataframe to be used for Travelling␣
 ↪Salesman Problem
loc1=[]
loc2=[]
quan=[]
for i in loc:
    for j in loc:
        loc1.append(i)
        loc2.append(j)
        quan.append(x[i,j].varValue)

d=pd.DataFrame(loc1,columns=['Start'])
d['Destination']=loc2
d['quantity']=quan
d
```

[55]:
	Start	Destination	quantity
0	U.S	U.S	0.0
1	U.S	Brazil	0.0
2	U.S	Canada	0.0
3	U.S	Mexico	0.0
4	U.S	Argentina	0.0
..	…	…	…
76	Uruguay	Argentina	0.0
77	Uruguay	Chile	0.0
78	Uruguay	Colombia	0.0
79	Uruguay	Puerto Rico	0.0
80	Uruguay	Uruguay	9.0

[81 rows x 3 columns]

[56]:
```python
loc1=[]
cap_p=[]
status=[]
for i in loc:
    for s in size:
        loc1.append(i)
        cap_p.append(s)
```

```
        status.append(y[i,s].varValue)
a=pd.DataFrame(loc1,columns=['location'])
a['capacity']=cap_p
a['status']=status
a
```

[56]:

	location	capacity	status
0	U.S	Low_Cap	0.0
1	U.S	High_Cap	0.0
2	Brazil	Low_Cap	0.0
3	Brazil	High_Cap	0.0
4	Canada	Low_Cap	0.0
5	Canada	High_Cap	1.0
6	Mexico	Low_Cap	0.0
7	Mexico	High_Cap	1.0
8	Argentina	Low_Cap	0.0
9	Argentina	High_Cap	1.0
10	Chile	Low_Cap	0.0
11	Chile	High_Cap	1.0
12	Colombia	Low_Cap	0.0
13	Colombia	High_Cap	1.0
14	Puerto Rico	Low_Cap	0.0
15	Puerto Rico	High_Cap	1.0
16	Uruguay	Low_Cap	0.0
17	Uruguay	High_Cap	1.0

[ ]: