Reading in Data and Graphs

In [1]:
```
import numpy as np
import pandas as pd
import networkx as nx
import matplotlib.pyplot as plt
import plotly.graph_objects as go
import seaborn as sns
! pip install openpyxl
```

```
Requirement already satisfied: openpyxl in c:\users\asus\anaconda3\envs\r-
tutorial\lib\site-packages (3.1.5)
Requirement already satisfied: et-xmlfile in c:\users\asus\anaconda3\envs
\r-tutorial\lib\site-packages (from openpyxl) (1.1.0)
```

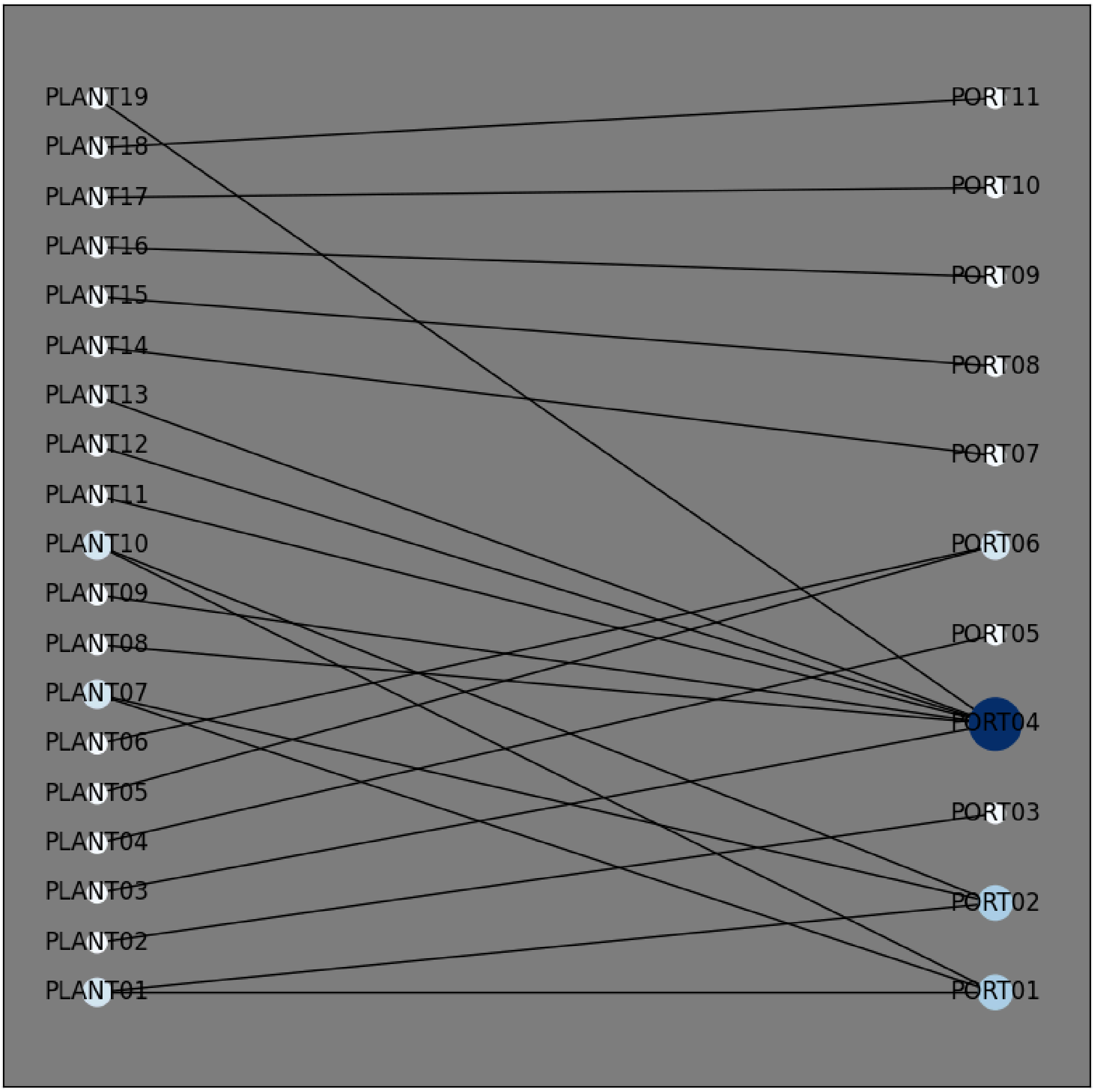
In [2]:
```
# reading in all the csv files
file = pd.ExcelFile(r"C:\Users\asus\Desktop\Data_sets\Supply chain logisitc

plant_ports = file.parse("PlantPorts")

order_list = file.parse("OrderList")

products_plants = file.parse("ProductsPerPlant")

vmi_plants = file.parse("VmiCustomers")

freight_rates = file.parse("FreightRates")

wh_cost = file.parse("WhCosts")


# changing column names
order_list.columns = [i.replace(" ", "_") for i in order_list.columns]

products_plants.columns = [i.replace(" ", "_") for i in products_plants.col

plant_ports.columns = [i.replace(" ", "_") for i in plant_ports.columns]

vmi_plants.columns = [i.replace(" ", "_") for i in vmi_plants.columns]

wh_cost.set_index("WH", inplace = True)
```

In [3]:
```
plant_ports_graph = nx.from_pandas_edgelist(plant_ports, source = "Plant_Co
```

Supply Chain Mapping:

Non Interactive with Networks

In [4]:
```
fig, ax = plt.subplots(figsize = (10,10))
ax.set_facecolor("Grey")

# specify layoyut of the graph
layout = nx.bipartite_layout(plant_ports_graph, plant_ports["Plant_Code"])

for i in layout:
    if i.startswith("PLANT"):
        layout[i][0] -= 0.1
    else:
        layout[i][0] += 0.1


# we want to map the degree of the node to a color/size
degrees = dict(plant_ports_graph.degree)
maps = [v*100 for v in degrees.values()]


# specify the color map
cmap = plt.cm.Blues

# keyword args that are the same for both functions
kwargs = {"pos": layout, "ax": ax}

nx.draw_networkx_nodes(plant_ports_graph, node_size = maps, node_color = ma
nx.draw_networkx_edges(plant_ports_graph, **kwargs)
nx.draw_networkx_labels(plant_ports_graph, pos = layout)
plt.show()
```



Interactive Version with Plotly

In [5]:
```
# get starting and ending points of the edges and add them to tha graph
layout = nx.bipartite_layout(plant_ports_graph, plant_ports["Plant_Code"])

edge_x = []
edge_y = []

for edge in plant_ports_graph.edges():
    x0, y0 = layout[edge[0]]
    x1, y1 = layout[edge[1]]

    edge_x.append(x0)
    edge_x.append(x1)
    edge_x.append(None)
    edge_y.append(y0)
    edge_y.append(y1)
    edge_y.append(None)

edge_trace = go.Scatter(x = edge_x, y = edge_y, line = dict(width = 0.5, co
```

In [6]:
```
# get cooerdinated of nodes and add them to the graph

node_x = []
node_y = []
for node in plant_ports_graph.nodes():
    x, y = layout[node]
    node_x.append(x)
    node_y.append(y)

maps = [v for v in degrees.values()]

node_trace = go.Scatter(
    x=node_x, y=node_y,
    mode='markers',
    hoverinfo='text',
    marker=dict(
        showscale=True,
        colorscale='YlGnBu',
        reversescale=True,
        color=maps,
        size=10,
        colorbar=dict(
            thickness=15,
            title='Node Connections',
            xanchor='left',
            titleside='right'
        ),
        line_width=2))

node_trace.text = [i + " Number of Links: " + str(degrees[i]) for i in degr
```

In [7]:
```
fig = go.Figure(data = [edge_trace, node_trace],
                layout = go.Layout(
                    title = '<br>Supply Chain',
                titlefont_size = 16,
                showlegend = False,
                hovermode = 'closest',
                margin = dict(b = 20, l = 5, r = 5, t = 40),
                annotations = [dict(text = "Factoris",
                                   showarrow = False,
                                   xref = "paper", yref = "paper",
                                    x = 0.005, y = -0.002),
                               dict(text = "Ports",
                                    showarrow = False,
                xref = "paper", yref = "paper",
                x = 0.95, y = -0.002)],
                xaxis = dict(showgrid = True, zeroline = False, showticklab
                yaxis =  dict(showgrid = True, zeroline = False, showtickla
               )

fig.write_html("html.html")
```

Most facilities have only one connection to a port. Port 4 is potentially the most important one as it has the most connections to the warehouse.

Preparing the Order Table:

The existing order table already contains a solution. We will delete those columns.

In [8]:
```
order_new = order_list.drop(columns = ["Order_Date", "Origin_Port",
                                      "Carrier", "Plant_Code", "TPT",
                                      "Service_Level", "Ship_ahead_day_coun
                                       "Ship_Late_Day_count"])

order_new.set_index("Order_ID", inplace = True)
order_new.to_csv("order_new.csv")
```

Preparing Freight Table:

In [9]:
```
freight_rates.drop(columns = ["dest_port_cd", "Carrier type",
                             "svc_cd"], inplace = True)

freight_rates.to_csv("FreightRates_mod.csv")
```

Problem Restrictions:

In [10]:
```
# given a product id, return the plants that can produce this product

def product_restriction(index):
    data = order_new.loc[index]
    product_id = data["Product_ID"]
    possible_plants = products_plants.loc[products_plants
                                          ["Product_ID"] == product_id ]
    return np.array(possible_plants["Plant_Code"])
```

In [11]:
```
# vmi restriction: check if a given customer has to be serviced
# by a specific facility, else return all facilities as possibilities.

def customer_restriction(index):
    data = order_new.loc[index]
    Customer_id = data["Customer"]
    possible_plants = vmi_plants.loc[vmi_plants["Customers"] ==
                                     Customer_id]
    if list(possible_plants["Plant_Code"]) == []:
        return plant_ports["Plant_Code"].unique()
    else:
        return np.array(possible_plants["Plant_Code"])
```

In [12]:
```
# combine both the product and vmi restriction.
# There will be orders for which only one, or possibly even 0,
# facilities can fullfil it

def check_order(Order_Id, length = True):
    if length:
        return len(np.intersect1d(customer_restriction(Order_Id),
                                  product_restriction(Order_Id)))
    else:
        return np.intersect1d(customer_restriction(Order_Id),
                              product_restriction(Order_Id))
```

In [13]:
```
# under the restrictions above, we can calculate the
# number of facilities that can process a given order.

order_new["decision_space_size"] = np.array(list(map(check_order,
                                                     order_new.index)))
```

In [14]:
```
order_new["decision_space_size"].value_counts()
```

Out[14]:
```
decision_space_size
1    6275
0    1045
4     982
2     785
3     127
5       1
Name: count, dtype: int64
```

We can see that for most orders, there is only facility that can handle the order. For ~ 1,000 there is no possible facility that can handle the order given our problem restrictions, we will exclude these orders from our further optimization problem.

Assigning Orders

Instead of using the specific rate for a carrier we will aggregate the rates for a given port. The main problem is that rates range from 0.03 to 128 which makes it hard to know the unit of measurement(e.g. /kg or /unit). Therefore I will average the rates for each port and use those as the costs.

In [15]:
```
freight_rates["rate"].describe()
```

Out[15]:
```
count    1540.000000
mean        2.892656
std         4.603877
min         0.033200
25%         0.470400
50%         1.661200
75%         3.932200
max       128.027200
Name: rate, dtype: float64
```

In [16]:
```
ports_agg = freight_rates.groupby(["orig_port_cd"]).agg(
avg_rate = ("rate", np.mean))
```

```
C:\Users\asus\AppData\Local\Temp\ipykernel_12776\613922709.py:1: FutureWar
ning:

The provided callable <function mean at 0x00000286716634C0> is currently u
sing SeriesGroupBy.mean. In a future version of pandas, the provided calla
ble will be used directly. To keep current behavior pass the string "mean"
instead.
```

In [17]:
```
# we will exclude orders that cannot be processed by any facility
# (i.e. where the decision space size == 0)

order_new = order_new.loc[order_new.decision_space_size != 0]
```

In [18]:
```
# return the possible plants that can process the order.

order_new["decision_space_plants"] = np.array((map(lambda x: check_order(
                                               x, length = False),
                                                  order_new.index)))
```

In [19]:
```
def min_cost(dec_space):

    plant_port_cost = {}

    wh = wh_cost.copy()
    min_cost = np.inf



    for plant in dec_space:
        plant_port_cost[plant] = wh.loc[plant].iloc[0]
        port_price, port = find_best_port(plant)
        plant_port_cost[plant] += port_price

        if plant_port_cost[plant] < min_cost:
            min_cost = plant_port_cost[plant]
            best_plant = plant
            best_port = port
            best_port_price = port_price

    return min_cost, best_plant, best_port_price, best_port
```

In [20]:
```
order_new.head()
```

Out[20]:

	Customer	Product_ID	Destination_Port	Unit_quantity	Weight	decision_spac
Order_ID						
1.447296e+09	V55555_53	1700106	PORT09	808	14.30	
1.447158e+09	V55555_53	1700106	PORT09	3188	87.94	
1.447139e+09	V55555_53	1700106	PORT09	2331	61.20	
1.447364e+09	V55555_53	1700106	PORT09	847	16.16	
1.447364e+09	V55555_53	1700106	PORT09	2163	52.34	

In [21]:
```
# given a port and the order specification return the carrier that
# can handle the product at the best price.

def find_best_port(plant_id):
    # choose the ports that have a connection to tha given plant and
    # then find the port with the lowest freight rate

    possible_ports = plant_ports.loc[(plant_ports.Plant_Code == plant_id) &
    possible_ports = ports_agg.loc[possible_ports]
    return possible_ports.loc[possible_ports["avg_rate"] == min(possible_po
```

In [22]:
```
order_new["decision"] = order_new["decision_space_plants"].apply(min_cost)
```

In [23]:
```
order_new['decision']
```

Out[23]:
```
Order_ID
1.447296e+09    (4.7563741745191, PLANT16, 2.8365666666666662,...
1.447158e+09    (4.7563741745191, PLANT16, 2.8365666666666662,...
1.447139e+09    (4.7563741745191, PLANT16, 2.8365666666666662,...
1.447364e+09    (4.7563741745191, PLANT16, 2.8365666666666662,...
1.447364e+09    (4.7563741745191, PLANT16, 2.8365666666666662,...
                                     ...
1.447372e+09    (10.456881296705, PLANT02, 9.979377777777778, ...
1.447372e+09    (10.456881296705, PLANT02, 9.979377777777778, ...
1.447328e+09    (10.456881296705, PLANT02, 9.979377777777778, ...
1.447358e+09    (10.456881296705, PLANT02, 9.979377777777778, ...
1.447287e+09    (10.456881296705, PLANT02, 9.979377777777778, ...
Name: decision, Length: 8170, dtype: object
```

In [24]:
```
order_id = float(input("Enter Order ID"))
array = order_new.loc[order_id]["decision"]
print('\n\n\033[1m'+ "Minimum Cost:", array[0])
print("Best Plant:", array[1])
print("Best Port Price:", array[2])
print("Best Port:", array[3])
```

```
Enter Order ID1447296446.7


Minimum Cost: 4.7563741745191
Best Plant: PLANT16
Best Port Price: 2.8365666666666662
Best Port: PORT09
```

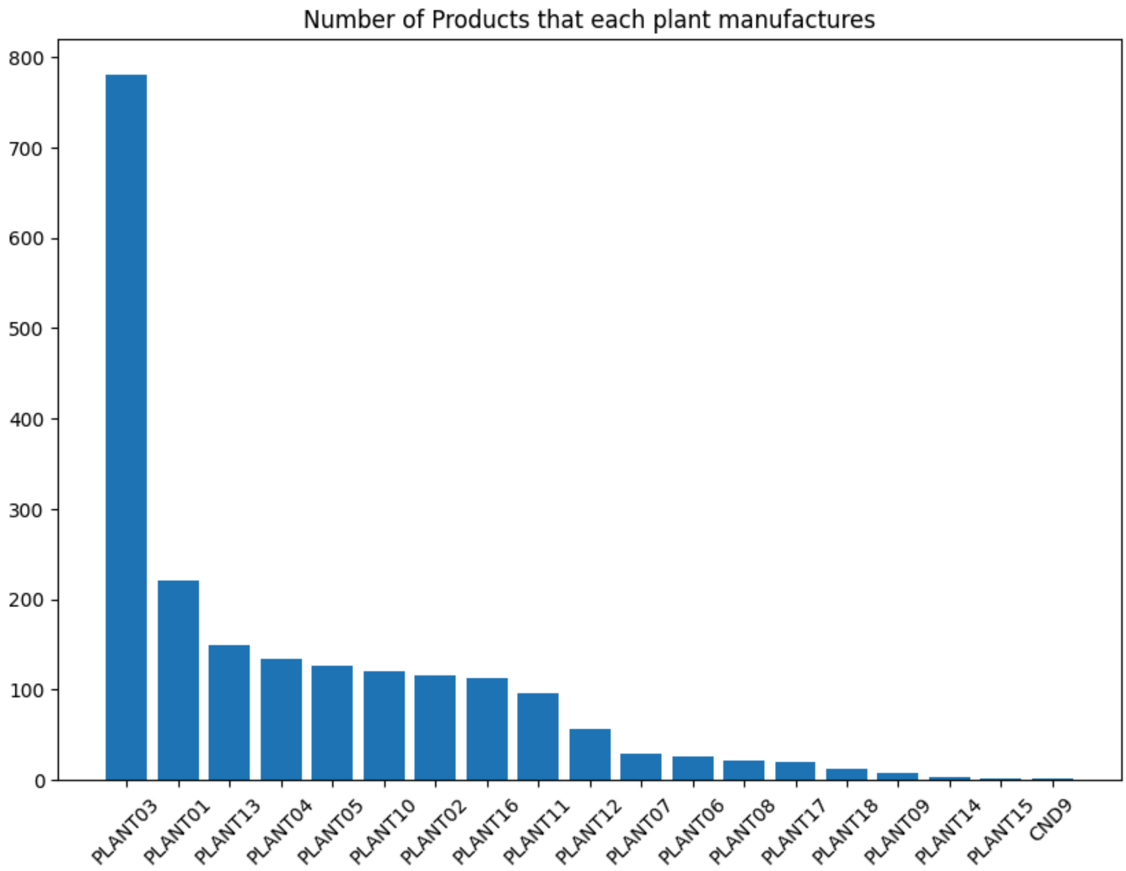
In [25]:
```
order_new["decision"].to_csv("Decision.csv")
```

In [26]:
```
products_plants.head()
```

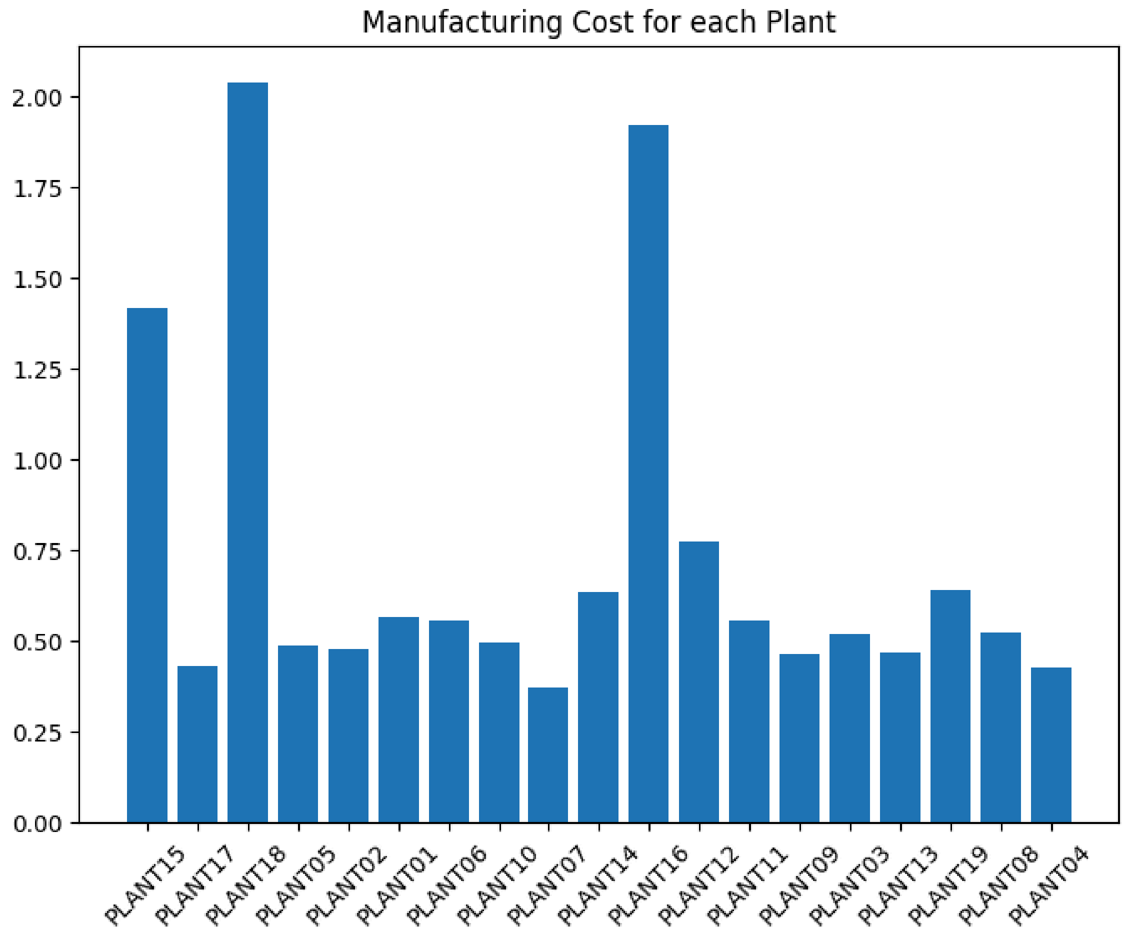
Out[26]:

	Plant_Code	Product_ID
0	PLANT15	1698815
1	PLANT17	1664419
2	PLANT17	1664426
3	PLANT17	1672826
4	PLANT17	1674916

In [27]:
```
fig, ax = plt.subplots(1,1, figsize=(10,7))
plt.xticks(rotation=45)
plant_counts = pd.DataFrame(products_plants["Plant_Code"].value_counts())
ax.bar(plant_counts.index, plant_counts.values.flatten())
plt.title("Number of Products that each plant manufactures")
plt.show()
```



In [28]:
```
fig, ax = plt.subplots(1,1, figsize=(8,6))
plt.xticks(rotation=45)
ax.bar(wh_cost.index, wh_cost["Cost/unit"])
plt.title("Manufacturing Cost for each Plant")
plt.show()
```



In [ ]: