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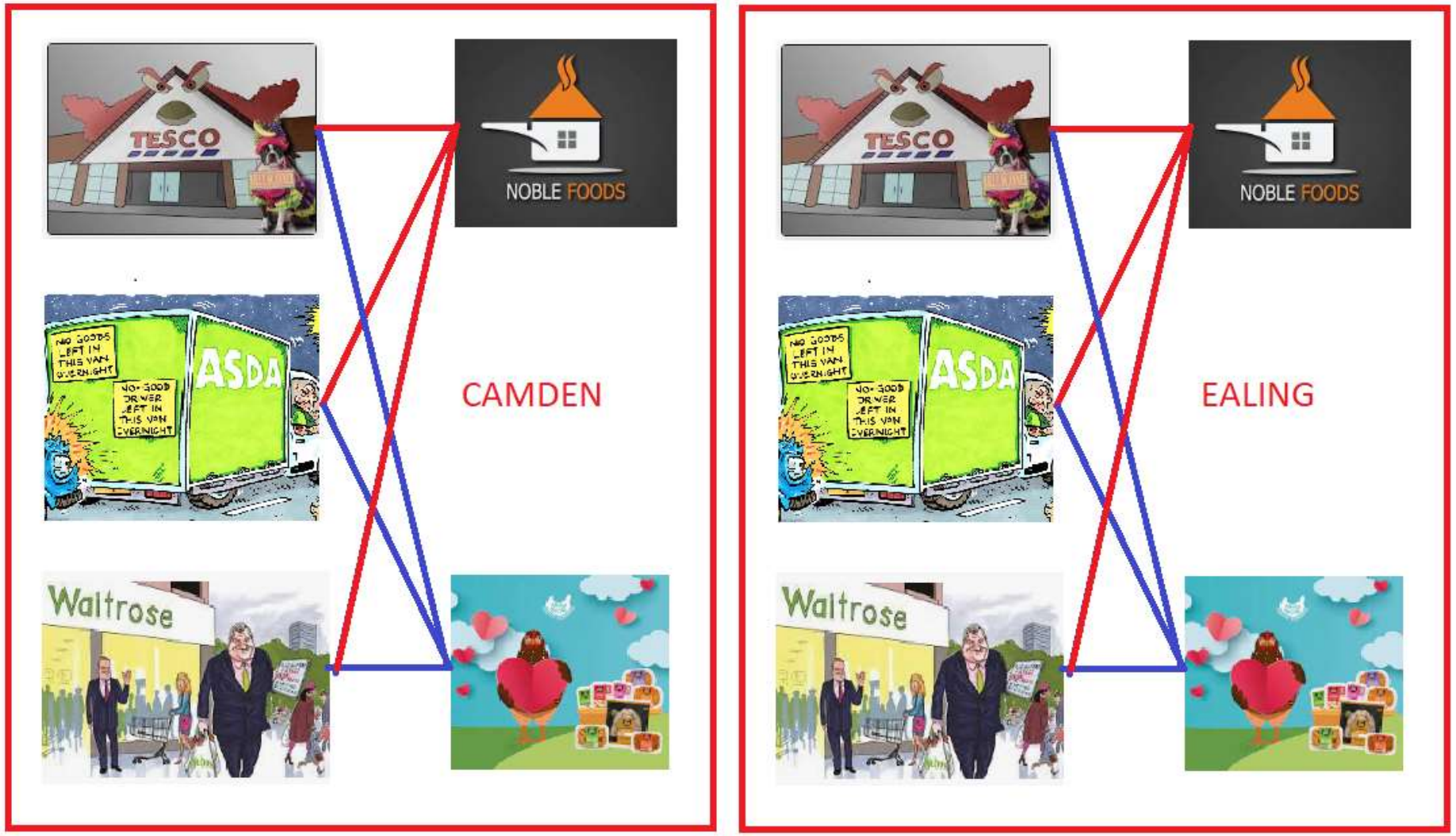
In [ ]:

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




# Problem statement:

We gave three supermarket brands (for example, Lidl, Tesco and Asda) we denote them Shop 1, Shop 2 and Shop 3. They have branches in Camden, Ealing, Greenwich, Hounslow, Richmond upon Thames, Hammersmith and Fulham, Kensington and Chelsea and City of Westminster. They use two suppliers that have branches in the same London Boroughs, we have historical probability of item being in the given supplier branch of London Borough. We know how many items each supplier can deliver per days.

We are given total number of items demanded by every supermarket brand and information about when (date) and where (London Borough) the given supermarket can accept part of this total demand but exact value is not provided. The supplier can deliver items to supermarkets from the same Borough only. We have weights or probability that total supply for the given location is going to a particular supermarket. The task is to find date, location and number of items should be delivered to all three supermarkets.

In [ ]:

```
# https://gist.github.com/brunosan/96288a8612894fca718aacbcc501ee09
# the following dhontAD code based on the link above
def dhontAD(nSeats, votes):
    """
    nSeats is the number of seats
    votes is an aaray of probabilities
    """
    t_votes = votes.copy()
    seats   = np.zeros(len(votes))
    #
    if sum(votes) > 0:
       while sum(seats) < nSeats:
             next_seat = np.argmax(t_votes)
             seats[next_seat] += 1
             t_votes[next_seat] = votes[next_seat] / (seats[next_seat] + 1)
    return seats
#
nSeats = 100 # we want to allocate 100 seats
votes = np.array([0.2, 0.3, 0.5])
dhontAD(nSeats, votes)
```

$$\max_{x} \quad \sum_{d}\sum_{b} w_1 \times x_{db1} + w_2 \times x_{db2} + \ldots + w_N \times x_{dbN}$$
$$\text{s.t.} \quad x \in X$$

we have one weight per supermarket; d is the date and b is the London borough or location; x is the number of items given date, London Borough and supermarket; X is the feasable set for x. Supply and Demand has to be from the same London Borough.

**Demand Weights could be weight of the objective function that are used in linear programming.**

| Demand Weight | | |
|---|---|---|
| Shop 1 | Shop 2 | Shop 3 |
| 0.2 | 0.3 | 0.5 |

**where** $w_1 = 0.2$, $w_2 = 0.3$ **and** $w_3 = 0.5$**.**

**The table below shows how many items is required by every supermarket in all considered locations during two days.**

| Shop_Demand | | |
|---|---|---|
| Shop 1 | Shop 2 | Shop 3 |
| 150 | 500 | 300 |

**Information about when (date) and where (London Borough) the given supermarket is available to accept part of the above total demand (see the table called Shop_Demand above) but how much it will accept it depends on the supply ib the given Borough and Demand Weights.**

If it is "+" (True) the the supermarket is available to accept the items on the particular date and London Borough (location) and it does not accept otherwise (when it is "-" or False).

| N | Date | London Borough | Shop Demand Availability | | |
|---|---|---|---|---|---|
| | | | Shop 1 | Shop 2 | Shop 3 |
| 1 | 11/06/2022 | Camden | - | - | - |
| 2 | 11/06/2022 | Ealing | - | - | + |
| 3 | 11/06/2022 | Greenwich | - | + | - |
| 4 | 11/06/2022 | Hounslow | - | + | + |
| 5 | 11/06/2022 | Richmond upon Thames | + | - | - |
| 6 | 11/06/2022 | Hammersmith and Fulham | + | - | + |
| 7 | 11/06/2022 | Kensington and Chelsea | + | + | - |
| 8 | 11/06/2022 | City of Westminster | + | + | + |
| 9 | 12/06/2022 | Camden | - | - | - |
| 10 | 12/06/2022 | Ealing | - | - | + |
| 11 | 12/06/2022 | Greenwich | - | + | - |
| 12 | 12/06/2022 | Hounslow | - | + | + |
| 13 | 12/06/2022 | Richmond upon Thames | + | - | - |
| 14 | 12/06/2022 | Hammersmith and Fulham | + | - | + |
| 15 | 12/06/2022 | Kensington and Chelsea | + | + | - |
| 16 | 12/06/2022 | City of Westminster | + | + | + |
| 17 | Total | - | 150 | 500 | 300 |

In [ ]:

```
# We define the INPUTS in this cell!!!
#
nShops = 3
#
dates = ["11/06/2022"] * 8 + ["12/06/2022"] * 8
London_Boroughs = ["Camden",
                   "Ealing",
                   "Greenwich",
                   "Hounslow",
                   "Richmond upon Thames",
                   "Hammersmith and Fulham",
                   "Kensington and Chelsea",
                   "City of Westminster"] * 2
#
Demand_Weights = {"Shop 1": 0.2, "Shop 2": 0.3, "Shop 3": 0.5}
print("Demand_Weights: ", Demand_Weights)
#
Shop_Demand    = {"Shop 1": 150, "Shop 2": 500, "Shop 3": 300}
print("Shop Demand: ", Shop_Demand)
#
Avalablity_Shop_1 = [False, False, False, False, True, True, True, True] * 2
Avalablity_Shop_2 = [False, False, True, True] * 4
Avalablity_Shop_3 = [False, True] * 8
demand = pd.DataFrame({"date": dates,
                       "London Borough": London_Boroughs,
                       "Avalablity Shop 1": Avalablity_Shop_1,
                       "Avalablity Shop 2": Avalablity_Shop_2,
                       "Avalablity Shop 3": Avalablity_Shop_3})
#
demand
```

**The information about Supply include the probability of supply over different London Borough (location) and daily total amount of the supplied items (see Table below).**

The probability could be different for different supplier but in our example it is the same for simplicity of presentation.

| N | Date | London Borough | Supply | | | |
|---|---|---|---|---|---|---|
| | | | Supplier 1 | | Supplier 2 | |
| | | | Probability | Daily Total | Probability | Daily Total |
| 1 | 11/06/2022 | Camden | 0.118 | 255 | 0.118 | 255 |
| 2 | 11/06/2022 | Ealing | 0.157 | | 0.157 | |
| 3 | 11/06/2022 | Greenwich | 0.118 | | 0.118 | |
| 4 | 11/06/2022 | Hounslow | 0.220 | | 0.220 | |
| 5 | 11/06/2022 | Richmond upon Thames | 0.078 | | 0.078 | |
| 6 | 11/06/2022 | Hammersmith and Fulham | 0.192 | | 0.192 | |
| 7 | 11/06/2022 | Kensington and Chelsea | 0.039 | | 0.039 | |
| 8 | 11/06/2022 | City of Westminster | 0.078 | | 0.078 | |
| 9 | 12/06/2022 | Camden | 0.118 | 510 | 0.118 | 255 |
| 10 | 12/06/2022 | Ealing | 0.157 | | 0.157 | |
| 11 | 12/06/2022 | Greenwich | 0.118 | | 0.118 | |
| 12 | 12/06/2022 | Hounslow | 0.220 | | 0.220 | |
| 13 | 12/06/2022 | Richmond upon Thames | 0.078 | | 0.078 | |
| 14 | 12/06/2022 | Hammersmith and Fulham | 0.192 | | 0.192 | |
| 15 | 12/06/2022 | Kensington and Chelsea | 0.039 | | 0.039 | |
| 16 | 12/06/2022 | City of Westminster | 0.078 | | 0.078 | |
| 17 | Total | | 2 | 765 | 2 | 510 |

In [ ]:

```
Daily_Total_Supplied_Quantity = {"Day 1, ALL Quantity, Supplier 1": 255,
                                 "Day 2, ALL Quantity, Supplier 1": 510,
                                 "Day 1, ALL Quantity, Supplier 2": 255,
                                 "Day 2, ALL Quantity, Supplier 2": 255}
#
print("Daily Total Supplied Quantity: ", Daily_Total_Supplied_Quantity)
#
prob_of_supply_per_borough = np.array([0.118, 0.157, 0.118, 0.220, 0.078, 0.192, 0.039, 0.078])
#
supply_df = pd.DataFrame({"date": dates,
                          "London Borough": London_Boroughs,
                          "supplier 1 prob": list(prob_of_supply_per_borough) * 2,
                          "supplier 2 prob": list(prob_of_supply_per_borough) * 2,
                          })
#
print("\n Supplier probability over divverent London Boroughs (location):")
print(supply_df)
```

# We finish definition of INPUTS at this point. Below we have our computations based on the above inputs.

**In the rest of the script we use blue colour to show values that can be considered as Inputs to the following cell and red one as the Output.**

# 1 We need to find how many supplied items is avalable for every supermarket given day and London Borough (location)

## 1.1 We multiply Shop Demand Availablity by Deman Weights

| N | Date | London Borough | Shop Demand Availability | | | Demand Weight | | |
|---|---|---|---|---|---|---|---|---|
| | | | Shop 1 | Shop 2 | Shop 3 | Shop 1 | Shop 2 | Shop 3 |
| 1 | 11/06/2022 | Camden | - | - | - | 0 | 0 | 0 |
| 2 | 11/06/2022 | Ealing | - | - | + | 0 | 0 | 0.5 |
| 3 | 11/06/2022 | Greenwich | - | + | - | 0 | 0.3 | 0 |
| 4 | 11/06/2022 | Hounslow | - | + | + | 0 | 0.3 | 0.5 |
| 5 | 11/06/2022 | Richmond upon Thames | + | - | - | 0.2 | 0 | 0 |
| 6 | 11/06/2022 | Hammersmith and Fulham | + | - | + | 0.2 | 0 | 0.5 |
| 7 | 11/06/2022 | Kensington and Chelsea | + | + | - | 0.2 | 0.3 | 0 |
| 8 | 11/06/2022 | City of Westminster | + | + | + | 0.2 | 0.3 | 0.5 |
| 9 | 12/06/2022 | Camden | - | - | - | 0 | 0 | 0 |
| 10 | 12/06/2022 | Ealing | - | - | + | 0 | 0 | 0.5 |
| 11 | 12/06/2022 | Greenwich | - | + | - | 0 | 0.3 | 0 |
| 12 | 12/06/2022 | Hounslow | - | + | + | 0 | 0.3 | 0.5 |
| 13 | 12/06/2022 | Richmond upon Thames | + | - | - | 0.2 | 0 | 0 |
| 14 | 12/06/2022 | Hammersmith and Fulham | + | - | + | 0.2 | 0 | 0.5 |
| 15 | 12/06/2022 | Kensington and Chelsea | + | + | - | 0.2 | 0.3 | 0 |
| 16 | 12/06/2022 | City of Westminster | + | + | + | 0.2 | 0.3 | 0.5 |
| 17 | Total | - | 150 | 500 | 300 | | - | |

In [ ]:

```
for i in range(1, nShops + 1):
    demand["Weight Shop " + str(i)] = \
    demand["Avalablity Shop " + str(i)].apply(lambda x: Demand_Weights["Shop " + str(i)] * x)
#
demand
```

## 1.2 For every row normalise Deman Weights after above multiplication that they sum to 1 over all supermarkets.

In order to normalise we divide weights by its sum. If the sum of Demand Weights in row is equal to 0 (see Camden Borough) we do not change anything - keep this row all zeros.

| N | Date | London Borough | Shop Demand Availability | | | Demand Weight | | | Row Normalised Weight | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Shop 1 | Shop 2 | Shop 3 | Shop 1 | Shop 2 | Shop 3 | Shop 1 | Shop 2 | Shop 3 |
| 1 | 11/06/2022 | Camden | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 11/06/2022 | Ealing | - | - | + | 0 | 0 | 0.5 | 0 | 0 | 1 |
| 3 | 11/06/2022 | Greenwich | - | + | - | 0 | 0.3 | 0 | 0 | 1 | 0 |
| 4 | 11/06/2022 | Hounslow | - | + | + | 0 | 0.3 | 0.5 | 0 | 0.375 | 0.625 |
| 5 | 11/06/2022 | Richmond upon Thames | + | - | - | 0.2 | 0 | 0 | 1 | 0 | 0 |
| 6 | 11/06/2022 | Hammersmith and Fulham | + | - | + | 0.2 | 0 | 0.5 | 0.285714 | 0 | 0.714286 |
| 7 | 11/06/2022 | Kensington and Chelsea | + | + | - | 0.2 | 0.3 | 0 | 0.4 | 0.6 | 0 |
| 8 | 11/06/2022 | City of Westminster | + | + | + | 0.2 | 0.3 | 0.5 | 0.2 | 0.3 | 0.5 |
| 9 | 12/06/2022 | Camden | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 12/06/2022 | Ealing | - | - | + | 0 | 0 | 0.5 | 0 | 0 | 1 |
| 11 | 12/06/2022 | Greenwich | - | + | - | 0 | 0.3 | 0 | 0 | 1 | 0 |
| 12 | 12/06/2022 | Hounslow | - | + | + | 0 | 0.3 | 0.5 | 0 | 0.375 | 0.625 |
| 13 | 12/06/2022 | Richmond upon Thames | + | - | - | 0.2 | 0 | 0 | 1 | 0 | 0 |
| 14 | 12/06/2022 | Hammersmith and Fulham | + | - | + | 0.2 | 0 | 0.5 | 0.285714 | 0 | 0.714286 |
| 15 | 12/06/2022 | Kensington and Chelsea | + | + | - | 0.2 | 0.3 | 0 | 0.4 | 0.6 | 0 |
| 16 | 12/06/2022 | City of Westminster | + | + | + | 0.2 | 0.3 | 0.5 | 0.2 | 0.3 | 0.5 |
| 17 | Total | - | 150 | 500 | 300 | - | | | | | |

In [ ]:

```
for i in range(1, nShops + 1):
    if i == 1:
       demand["Weight Shop SUM"] =  demand["Weight Shop " + str(i)].copy()
    else:
       demand["Weight Shop SUM"] += demand["Weight Shop " + str(i)].copy()
#
for i in range(1, nShops + 1):
    demand["row Normalised Weight Shop " + str(i)] = \
    demand.apply(lambda x: x["Weight Shop " + str(i)] / x["Weight Shop SUM"] if x["Weight Shop SUM"] > 0 else 0, \
                 axis = 1)
#
demand
```

## 1.3 Find the quantity of items that suppliers can provide for the given date and London Borough (location).

**For every date we apply D'hont algorithm that uses Supplier probabilities (vector of eight elements, for example, (0.118, 0.157, 0.118, 0.220, 0.078, 0.192, 0.039, 0.078)) and Supplier Total (for example, 255) given the date and supplier . In our further calculation we only need all available supply (see column "ALL" below) per London Borough.**

| N | Date | London Borough | Supply | | | | | | ALL |
|---|---|---|---|---|---|---|---|---|---|
| | | | Supplier 1 | | | Supplier 2 | | | |
| | | | Probability | Quantity | Total | Probability | Quantity | Total | |
| 1 | 11/06/2022 | Camden | 0.118 | 30 | 255 | 0.118 | 30 | 255 | 60 |
| 2 | 11/06/2022 | Ealing | 0.157 | 40 | | 0.157 | 40 | | 80 |
| 3 | 11/06/2022 | Greenwich | 0.118 | 30 | | 0.118 | 30 | | 60 |
| 4 | 11/06/2022 | Hounslow | 0.220 | 56 | | 0.220 | 56 | | 112 |
| 5 | 11/06/2022 | Richmond upon Thames | 0.078 | 20 | | 0.078 | 20 | | 40 |
| 6 | 11/06/2022 | Hammersmith and Fulham | 0.192 | 49 | | 0.192 | 49 | | 98 |
| 7 | 11/06/2022 | Kensington and Chelsea | 0.039 | 10 | | 0.039 | 10 | | 20 |
| 8 | 11/06/2022 | City of Westminster | 0.078 | 20 | | 0.078 | 20 | | 40 |
| 9 | 12/06/2022 | Camden | 0.118 | 60 | 510 | 0.118 | 30 | 255 | 90 |
| 10 | 12/06/2022 | Ealing | 0.157 | 80 | | 0.157 | 40 | | 120 |
| 11 | 12/06/2022 | Greenwich | 0.118 | 60 | | 0.118 | 30 | | 90 |
| 12 | 12/06/2022 | Hounslow | 0.220 | 112 | | 0.220 | 56 | | 168 |
| 13 | 12/06/2022 | Richmond upon Thames | 0.078 | 40 | | 0.078 | 20 | | 60 |
| 14 | 12/06/2022 | Hammersmith and Fulham | 0.192 | 98 | | 0.192 | 49 | | 147 |
| 15 | 12/06/2022 | Kensington and Chelsea | 0.039 | 20 | | 0.039 | 10 | | 30 |
| 16 | 12/06/2022 | City of Westminster | 0.078 | 40 | | 0.078 | 20 | | 60 |
| 17 | Total | | | 765 | 765 | | 510 | 510 | 1275 |

In [ ]:

```
#
nSuppliers = 2
nDays      = 2
#
Dates = ["11/06/2022", "12/06/2022"]
#
Quantity_Supplied_given_Supplier = {"1": [], "2": []}
#
for i in range(1, nSuppliers + 1):
    for k in range(1, len(Dates) + 1):
        Date = Dates[k - 1]
        prob                   = supply_df[supply_df["date"] == Date]["supplier " + str(i) + " prob"].values
        supplied_daily_amount = Daily_Total_Supplied_Quantity["Day " + str(k) + \
                                                              ", ALL Quantity, Supplier " + str(i)]
        #
        Quantity_Supplied_given_Supplier_Date = dhontAD(supplied_daily_amount, prob)
        #
        Quantity_Supplied_given_Supplier[str(i)] = \
        Quantity_Supplied_given_Supplier[str(i)] + list(Quantity_Supplied_given_Supplier_Date)
    #
    supply_df["supplier " + str(i) + " quantity"] = Quantity_Supplied_given_Supplier[str(i)]
    supply_df["supplier " + str(i) + " quantity"] =  supply_df["supplier " + str(i) + " quantity"].astype(int)
#
supply_df["Supplier ALL"] = supply_df["supplier 1 quantity"] + supply_df["supplier 2 quantity"]
#
supply_df
```

# 1.4 Evaluate how many items can be supplied to the given shop

**We join demand and supply_df tables and then apply DHont algorithm for every row using Row Normalised Weights (see demand table above) and Supplier ALL (see supply_df above) as following:**

| N | Date | London Borough | Shop Demand Availability | | | Demand Weight | | | Row Normalised Weight | | | Supply AS Demand | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Shop 1 | Shop 2 | Shop 3 | Shop 1 | Shop 2 | Shop 3 | Shop 1 | Shop 2 | Shop 3 | Shop 1 | Shop 2 | Shop 3 |
| 1 | 11/06/2022 | Camden | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 11/06/2022 | Ealing | - | - | + | 0 | 0 | 0.5 | 0 | 0 | 1 | 0 | 0 | 80 |
| 3 | 11/06/2022 | Greenwich | - | + | - | 0 | 0.3 | 0 | 0 | 1 | 0 | 0 | 60 | 0 |
| 4 | 11/06/2022 | Hounslow | - | + | + | 0 | 0.3 | 0.5 | 0 | 0.375 | 0.625 | 0 | 42 | 70 |
| 5 | 11/06/2022 | Richmond upon Thames | + | - | - | 0.2 | 0 | 0 | 1 | 0 | 0 | 40 | 0 | 0 |
| 6 | 11/06/2022 | Hammersmith and Fulham | + | - | + | 0.2 | 0 | 0.5 | 0.285714 | 0 | 0.714286 | 28 | 0 | 70 |
| 7 | 11/06/2022 | Kensington and Chelsea | + | + | - | 0.2 | 0.3 | 0 | 0.4 | 0.6 | 0 | 8 | 12 | 0 |
| 8 | 11/06/2022 | City of Westminster | + | + | + | 0.2 | 0.3 | 0.5 | 0.2 | 0.3 | 0.5 | 8 | 12 | 20 |
| 9 | 12/06/2022 | Camden | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 12/06/2022 | Ealing | - | - | + | 0 | 0 | 0.5 | 0 | 0 | 1 | 0 | 0 | 120 |
| 11 | 12/06/2022 | Greenwich | - | + | - | 0 | 0.3 | 0 | 0 | 1 | 0 | 0 | 90 | 0 |
| 12 | 12/06/2022 | Hounslow | - | + | + | 0 | 0.3 | 0.5 | 0 | 0.375 | 0.625 | 0 | 63 | 105 |
| 13 | 12/06/2022 | Richmond upon Thames | + | - | - | 0.2 | 0 | 0 | 1 | 0 | 0 | 60 | 0 | 0 |
| 14 | 12/06/2022 | Hammersmith and Fulham | + | - | + | 0.2 | 0 | 0.5 | 0.285714 | 0 | 0.714286 | 42 | 0 | 105 |
| 15 | 12/06/2022 | Kensington and Chelsea | + | + | - | 0.2 | 0.3 | 0 | 0.4 | 0.6 | 0 | 12 | 18 | 0 |
| 16 | 12/06/2022 | City of Westminster | + | + | + | 0.2 | 0.3 | 0.5 | 0.2 | 0.3 | 0.5 | 12 | 18 | 30 |
| 17 | Total | - | 150 | 500 | 300 | - | | | | | | 210 | 315 | 600 |

**Note that, DHont algorithm in this case can be implemented in BigQuery using Keras because the number of shops given the supermarket network in the London Borough is less than 233155. this constrain comes from restriction that Keras in BigQuery process data in batches around 233155 elements in the batch.**

In [ ]:
```
demand_supply = demand.merge(supply_df, on = ["date", "London Borough"])
r_norm_shop = "row Normalised Weight Shop "
demand_supply["Supply AS Demand"] = demand_supply.apply(lambda x: dhontAD(x["Supplier ALL"], \
                                        x[[r_norm_shop + "1", r_norm_shop + "2", r_norm_shop + "3"]].values), \
                                                    axis = 1)
#
for i in range(1, nShops + 1):
    demand_supply["Supply AS Demand Shop " + str(i)] = demand_supply["Supply AS Demand"].apply( \
                                                                        lambda x: int(x[i - 1]))
#
Total_Supply_AS_Demand = demand_supply[["Supply AS Demand Shop 1", "Supply AS Demand Shop 2", \
                                        "Supply AS Demand Shop 3"]].sum(axis = 0)
print("Total Supply AS Demand:")
print(Total_Supply_AS_Demand)
#
demand_supply
```

# 1.5 Evaluation of Available Demand

**We find the minimum between what is required and what is available for the given supermarket network:**

| Super Market | Demand | Supply | Available Demand |
|---|---|---|---|
| Shop 1 | 150 | 210 | 150 |
| Shop 2 | 500 | 315 | 315 |
| Shop 3 | 300 | 600 | 300 |

In [ ]:
```
Total_Supply_AS_Demand = demand_supply[["Supply AS Demand Shop 1", \
                                        "Supply AS Demand Shop 2", "Supply AS Demand Shop 3"]].sum(axis = 0)
print("Total Supply AS Demand:")
print(Total_Supply_AS_Demand)
Available_Demand = {}
for i in range(1, nShops + 1):
    Available_Demand["shop " + str(i)] = min(Shop_Demand["Shop " + str(i)], \
                                             Total_Supply_AS_Demand["Supply AS Demand Shop " + str(i)])
#
print("Available Demand: ", Available_Demand)
```

# 1.6 Summary

**The only purpose of the Section 1 is to find Available Demand per supermarket or demand that can be fulfill**

```
Available Demand:  {'shop 1': 150, 'shop 2': 315, 'shop 3': 300}
```

and Supply AS Demand that can be used for weight calculation in the nexr Section:

| Supply AS Demand | | |
|---|---|---|
| Shop 1 | Shop 2 | Shop 3 |
| 0 | 0 | 0 |
| 0 | 0 | 80 |
| 0 | 60 | 0 |
| 0 | 42 | 70 |
| 40 | 0 | 0 |
| 28 | 0 | 70 |
| 8 | 12 | 0 |
| 8 | 12 | 20 |
| 0 | 0 | 0 |
| 0 | 0 | 120 |
| 0 | 90 | 0 |
| 0 | 63 | 105 |
| 60 | 0 | 0 |
| 42 | 0 | 105 |
| 12 | 18 | 0 |
| 12 | 18 | 30 |
| 210 | 315 | 600 |

# 2. Final Allocation of Items given Date, Borough and Shop

# 2.1 Column Normalise Weights

For every shop of Supply AS Demand win order to compute weight we divide the every value of Supply AS Demand by the corresponding column total. If we sum any column of the obtained weight we get 1.

| N | Date | London Borough | Supply AS Demand | | | Column Normalised Weight | | |
|---|---|---|---|---|---|---|---|---|
| | | | Shop 1 | Shop 2 | Shop 3 | Shop 1 | Shop 2 | Shop 3 |
| 1 | 11/06/2022 | Camden | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 11/06/2022 | Ealing | 0 | 0 | 80 | 0 | 0 | 0.133333 |
| 3 | 11/06/2022 | Greenwich | 0 | 60 | 0 | 0 | 0.190476 | 0 |
| 4 | 11/06/2022 | Hounslow | 0 | 42 | 70 | 0 | 0.133333 | 0.116667 |
| 5 | 11/06/2022 | Richmond upon Thames | 40 | 0 | 0 | 0.190476 | 0 | 0 |
| 6 | 11/06/2022 | Hammersmith and Fulham | 28 | 0 | 70 | 0.133333 | 0 | 0.116667 |
| 7 | 11/06/2022 | Kensington and Chelsea | 8 | 12 | 0 | 0.038095 | 0.038095 | 0 |
| 8 | 11/06/2022 | City of Westminster | 8 | 12 | 20 | 0.038095 | 0.038095 | 0.033333 |
| 9 | 11/06/2022 | Camden | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 12/06/2022 | Ealing | 0 | 0 | 120 | 0 | 0 | 0.2 |
| 11 | 12/06/2022 | Greenwich | 0 | 90 | 0 | 0 | 0.285714 | 0 |
| 12 | 12/06/2022 | Hounslow | 0 | 63 | 105 | 0 | 0.2 | 0.175 |
| 13 | 12/06/2022 | Richmond upon Thames | 60 | 0 | 0 | 0.285714 | 0 | 0 |
| 14 | 12/06/2022 | Hammersmith and Fulham | 42 | 0 | 105 | 0.2 | 0 | 0.175 |
| 15 | 12/06/2022 | Kensington and Chelsea | 12 | 18 | 0 | 0.057143 | 0.057143 | 0 |
| 15 | 12/06/2022 | City of Westminster | 12 | 18 | 30 | 0.057143 | 0.057143 | 0.05 |
| 17 | Total | - | 210 | 315 | 600 | 1 | 1 | 1 |

In [ ]:

```
# Perform allocation for one shop at a time
for i in range(1, nShops + 1):
    total = demand_supply["Supply AS Demand Shop " + str(i)].sum()
    demand_supply["Column Normalised Weight " + str(i)] = demand_supply["Supply AS Demand Shop " + str(i)] / total
#
demand_supply[["date", "London Borough", "Supply AS Demand Shop 1", \
               "Supply AS Demand Shop 2", "Supply AS Demand Shop 3", \
               "Column Normalised Weight 1", "Column Normalised Weight 2", "Column Normalised Weight 3"]]
```

## 2.2 Final Allocations of Items to Shops

We use the column normalised weight and Available Demand as inputs to DHont algorithm. Output of Dhont algorithm is the final allocation of Items to the shop as following:

| N | Date | London Borough | Supply AS Demand | | | Column Normalised Weight | | | Final Allocation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Shop 1 | Shop 2 | Shop 3 | Shop 1 | Shop 2 | Shop 3 | Shop 1 | Shop 2 | Shop 3 |
| 1 | 11/06/2022 | Camden | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 11/06/2022 | Ealing | 0 | 0 | 80 | 0 | 0 | 0.133333 | 0 | 0 | 40 |
| 3 | 11/06/2022 | Greenwich | 0 | 60 | 0 | 0 | 0.190476 | 0 | 0 | 60 | 0 |
| 4 | 11/06/2022 | Hounslow | 0 | 42 | 70 | 0 | 0.133333 | 0.116667 | 0 | 42 | 35 |
| 5 | 11/06/2022 | Richmond upon Thames | 40 | 0 | 0 | 0.190476 | 0 | 0 | 29 | 0 | 0 |
| 6 | 11/06/2022 | Hammersmith and Fulham | 28 | 0 | 70 | 0.133333 | 0 | 0.116667 | 20 | 0 | 35 |
| 7 | 11/06/2022 | Kensington and Chelsea | 8 | 12 | 0 | 0.038095 | 0.038095 | 0 | 5 | 12 | 0 |
| 8 | 11/06/2022 | City of Westminster | 8 | 12 | 20 | 0.038095 | 0.038095 | 0.033333 | 5 | 12 | 10 |
| 9 | 11/06/2022 | Camden | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 12/06/2022 | Ealing | 0 | 0 | 120 | 0 | 0 | 0.2 | 0 | 0 | 60 |
| 11 | 12/06/2022 | Greenwich | 0 | 90 | 0 | 0 | 0.285714 | 0 | 0 | 90 | 0 |
| 12 | 12/06/2022 | Hounslow | 0 | 63 | 105 | 0 | 0.2 | 0.175 | 0 | 63 | 53 |
| 13 | 12/06/2022 | Richmond upon Thames | 60 | 0 | 0 | 0.285714 | 0 | 0 | 44 | 0 | 0 |
| 14 | 12/06/2022 | Hammersmith and Fulham | 42 | 0 | 105 | 0.2 | 0 | 0.175 | 31 | 0 | 52 |
| 15 | 12/06/2022 | Kensington and Chelsea | 12 | 18 | 0 | 0.057143 | 0.057143 | 0 | 8 | 18 | 0 |
| 15 | 12/06/2022 | City of Westminster | 12 | 18 | 30 | 0.057143 | 0.057143 | 0.05 | 8 | 18 | 15 |
| 17 | Total | - | 210 | 315 | 600 | 1 | 1 | 1 | 150 | 315 | 300 |

In [ ]:

```
# Perform allocatio for one shop at a time
for i in range(1, nShops + 1):
    available = Available_Demand["shop " + str(i)]
    print("Avalaible Demand Shop " + str(i) + ": ",  available)
    #
    demand_supply["Final Allocation Shop " + str(i)] = dhontAD(available, \
           demand_supply["Column Normalised Weight " + str(i)].values / total)
    demand_supply["Final Allocation Shop " + str(i)] = demand_supply["Final Allocation Shop " + str(i)].astype(int)
#
demand_supply[["date", "London Borough",  "Column Normalised Weight 1", \
               "Column Normalised Weight 2", "Column Normalised Weight 3", \
               "Final Allocation Shop 1", "Final Allocation Shop 2", "Final Allocation Shop 3"]]
```

**Test: Available Demand has to be equal to the corresponding Final Allocation**

In [ ]:

```
# Test: final Allocation should be equalt to Available_Demand.
print("Available_Demand: ", Available_Demand)
demand_supply[["Final Allocation Shop 1", "Final Allocation Shop 2", "Final Allocation Shop 3"]].sum(axis = 0)
```