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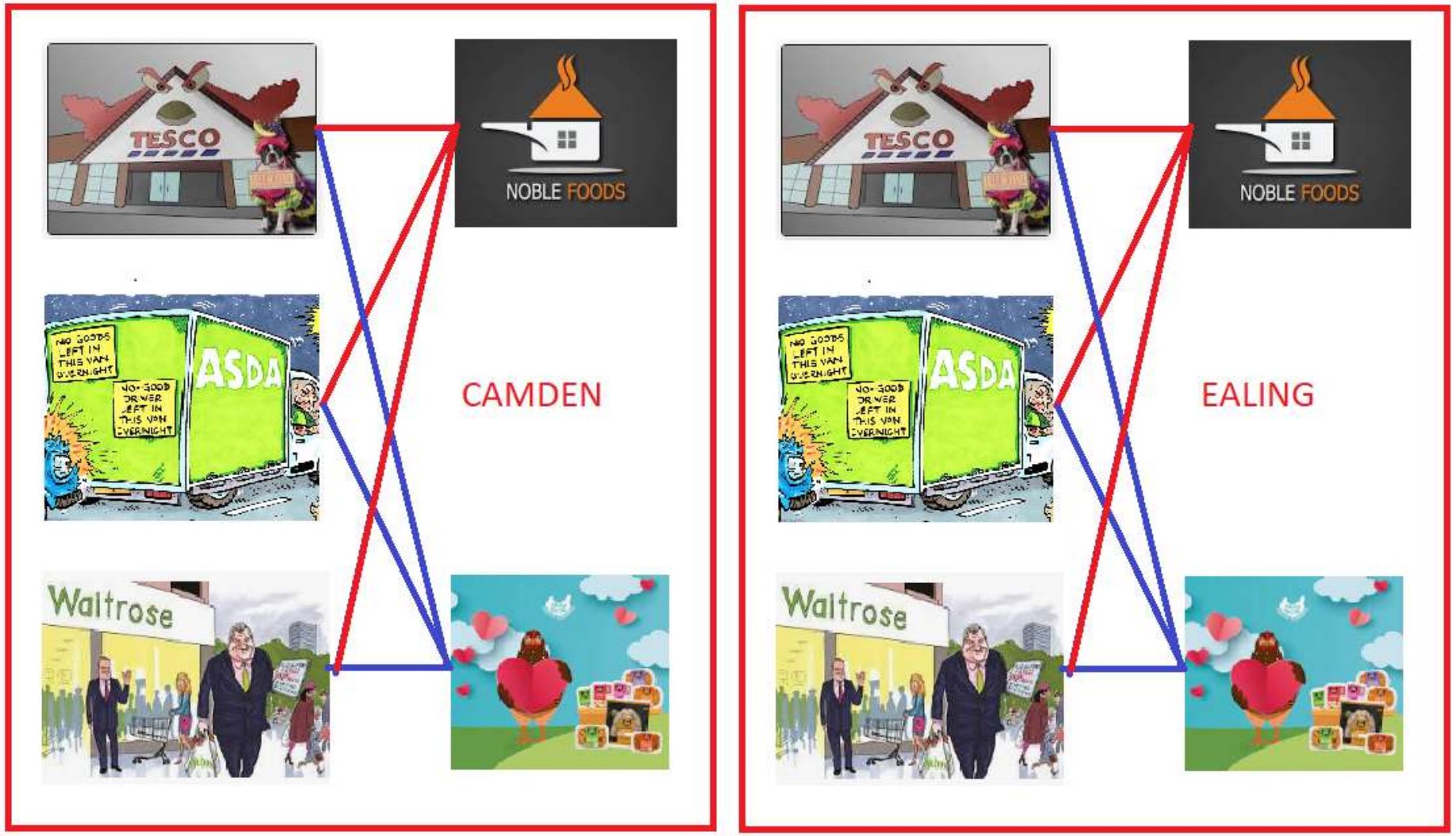
In [1]:

```
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 [2]:
```
# 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)
```

Out[2]:
```
array([20., 30., 50.])
```

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

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 [3]:

```
# 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
```

```
Demand_Weights:  {'Shop 1': 0.2, 'Shop 2': 0.3, 'Shop 3': 0.5}
Shop Demand:  {'Shop 1': 150, 'Shop 2': 500, 'Shop 3': 300}
```

Out[3]:

	date	London Borough	Avalablity Shop 1	Avalablity Shop 2	Avalablity Shop 3
0	11/06/2022	Camden	False	False	False
1	11/06/2022	Ealing	False	False	True
2	11/06/2022	Greenwich	False	True	False

	date	London Borough	Avalablity Shop 1	Avalablity Shop 2	Avalablity Shop 3
3	11/06/2022	Hounslow	False	True	True
4	11/06/2022	Richmond upon Thames	True	False	False
5	11/06/2022	Hammersmith and Fulham	True	False	True
6	11/06/2022	Kensington and Chelsea	True	True	False
7	11/06/2022	City of Westminster	True	True	True
8	12/06/2022	Camden	False	False	False
9	12/06/2022	Ealing	False	False	True
10	12/06/2022	Greenwich	False	True	False
11	12/06/2022	Hounslow	False	True	True
12	12/06/2022	Richmond upon Thames	True	False	False
13	12/06/2022	Hammersmith and Fulham	True	False	True
14	12/06/2022	Kensington and Chelsea	True	True	False
15	12/06/2022	City of Westminster	True	True	True

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 [4]:

```
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)
```

```
Daily Total Supplied Quantity:  {'Day 1, ALL Quantity, Supplier 1': 255, 'Day 2, ALL Quantity, Supplier 1': 510, 'D
ay 1, ALL Quantity, Supplier 2': 255, 'Day 2, ALL Quantity, Supplier 2': 255}

 Supplier probability over divverent London Boroughs (location):
          date          London Borough  supplier 1 prob  supplier 2 prob
0   11/06/2022                  Camden            0.118            0.118
1   11/06/2022                  Ealing            0.157            0.157
2   11/06/2022               Greenwich            0.118            0.118
3   11/06/2022                Hounslow            0.220            0.220
4   11/06/2022    Richmond upon Thames            0.078            0.078
5   11/06/2022  Hammersmith and Fulham            0.192            0.192
6   11/06/2022  Kensington and Chelsea            0.039            0.039
7   11/06/2022     City of Westminster            0.078            0.078
8   12/06/2022                  Camden            0.118            0.118
9   12/06/2022                  Ealing            0.157            0.157
10  12/06/2022               Greenwich            0.118            0.118
11  12/06/2022                Hounslow            0.220            0.220
12  12/06/2022    Richmond upon Thames            0.078            0.078
13  12/06/2022  Hammersmith and Fulham            0.192            0.192
14  12/06/2022  Kensington and Chelsea            0.039            0.039
15  12/06/2022     City of Westminster            0.078            0.078
```

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.

I have developed the following algorithm for item allocation:

1) get the number of possible supplied items per date, Borough and supplier. In order to find this number for t he given date and supplier apply Dhondt method using probability of the supply over locations and total number o f possible supplied items per date;
2) multiplied weights that are used in the optimization (one weight per supermarket in your case) by shop availa bility or demand (see symbols of "+" and "-" in excel table, "+" is when the shop is available to accept or need some items and "-" otherwise. Instead of "+" and "-" you can use True and False or 1 and 0, respectively;
3) normalised demand weight obtained in 2) for every row in such a way they they some to 1 unless they all equal to 0. In order to do so divide weights by it sum. Output is "Row Normalised Weight" (see Excel spreadsheet or no tebook);
4) compute the number of available items for given supermarket for every combintion of date and London Borough (see Excel column "Supply AS Demand"). To find it apply Dhondt algorithm for every row of "Row Normalised Weigh t" (for example, see Excel spreadsheet) and the corresponding value of "Supply ALL";
5) sum column of "Supply AS Demand" for every shop to find how many items are available from the supply per sup ermarket and find minimum between this value and the corresponding value that is demanded by the corresponding s upermarket . The result of this operation is the row in Excel called "MINIMUM of Demand Total and Supply AS Dema nd Total". It is the number of items that can be delivered by suppliers and are required by supermarkets;
6) find "Column Normalised Weight" where we divide every "Supply AS Demand" column by its sum;
7) calculate the "Final Allocation" by applying Dhondt algorithm to every column of "Column Normalised Weight" a nd the corresponding value of the row called "MINIMUM of Demand Total and Supply AS Demand Total" (see Excel sp readsheet).

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 [5]:

```
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
```

Out[5]:

	date	London Borough	Avalablity Shop 1	Avalablity Shop 2	Avalablity Shop 3	Weight Shop 1	Weight Shop 2	Weight Shop 3
0	11/06/2022	Camden	False	False	False	0.0	0.0	0.0
1	11/06/2022	Ealing	False	False	True	0.0	0.0	0.5
2	11/06/2022	Greenwich	False	True	False	0.0	0.3	0.0
3	11/06/2022	Hounslow	False	True	True	0.0	0.3	0.5
4	11/06/2022	Richmond upon Thames	True	False	False	0.2	0.0	0.0
5	11/06/2022	Hammersmith and Fulham	True	False	True	0.2	0.0	0.5
6	11/06/2022	Kensington and Chelsea	True	True	False	0.2	0.3	0.0
7	11/06/2022	City of Westminster	True	True	True	0.2	0.3	0.5
8	12/06/2022	Camden	False	False	False	0.0	0.0	0.0
9	12/06/2022	Ealing	False	False	True	0.0	0.0	0.5
10	12/06/2022	Greenwich	False	True	False	0.0	0.3	0.0
11	12/06/2022	Hounslow	False	True	True	0.0	0.3	0.5
12	12/06/2022	Richmond upon Thames	True	False	False	0.2	0.0	0.0
13	12/06/2022	Hammersmith and Fulham	True	False	True	0.2	0.0	0.5
14	12/06/2022	Kensington and Chelsea	True	True	False	0.2	0.3	0.0
15	12/06/2022	City of Westminster	True	True	True	0.2	0.3	0.5

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 [6]:

```
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
```

Out[6]:

	date	London Borough	Avalablity Shop 1	Avalablity Shop 2	Avalablity Shop 3	Weight Shop 1	Weight Shop 2	Weight Shop 3	Weight Shop SUM	row Normalised Weight Shop 1	row Normalised Weight Shop 2	row Normalised Weight Shop 3
0	11/06/2022	Camden	False	False	False	0.0	0.0	0.0	0.0	0.000000	0.000	0.000000
1	11/06/2022	Ealing	False	False	True	0.0	0.0	0.5	0.5	0.000000	0.000	1.000000
2	11/06/2022	Greenwich	False	True	False	0.0	0.3	0.0	0.3	0.000000	1.000	0.000000
3	11/06/2022	Hounslow	False	True	True	0.0	0.3	0.5	0.8	0.000000	0.375	0.625000
4	11/06/2022	Richmond upon Thames	True	False	False	0.2	0.0	0.0	0.2	1.000000	0.000	0.000000
5	11/06/2022	Hammersmith and Fulham	True	False	True	0.2	0.0	0.5	0.7	0.285714	0.000	0.714286
6	11/06/2022	Kensington and Chelsea	True	True	False	0.2	0.3	0.0	0.5	0.400000	0.600	0.000000
7	11/06/2022	City of Westminster	True	True	True	0.2	0.3	0.5	1.0	0.200000	0.300	0.500000
8	12/06/2022	Camden	False	False	False	0.0	0.0	0.0	0.0	0.000000	0.000	0.000000
9	12/06/2022	Ealing	False	False	True	0.0	0.0	0.5	0.5	0.000000	0.000	1.000000
10	12/06/2022	Greenwich	False	True	False	0.0	0.3	0.0	0.3	0.000000	1.000	0.000000
11	12/06/2022	Hounslow	False	True	True	0.0	0.3	0.5	0.8	0.000000	0.375	0.625000
12	12/06/2022	Richmond upon Thames	True	False	False	0.2	0.0	0.0	0.2	1.000000	0.000	0.000000

	date	London Borough	Avalablity Shop 1	Avalablity Shop 2	Avalablity Shop 3	Weight Shop 1	Weight Shop 2	Weight Shop 3	Weight Shop SUM	row Normalised Weight Shop 1	row Normalised Weight Shop 2	row Normalised Weight Shop 3
13	12/06/2022	Hammersmith and Fulham	True	False	True	0.2	0.0	0.5	0.7	0.285714	0.000	0.714286
14	12/06/2022	Kensington and Chelsea	True	True	False	0.2	0.3	0.0	0.5	0.400000	0.600	0.000000
15	12/06/2022	City of Westminster	True	True	True	0.2	0.3	0.5	1.0	0.200000	0.300	0.500000

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 [7]:

```
#
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
```

Out[7]:

	date	London Borough	supplier 1 prob	supplier 2 prob	supplier 1 quantity	supplier 2 quantity	Supplier ALL
0	11/06/2022	Camden	0.118	0.118	30	30	60
1	11/06/2022	Ealing	0.157	0.157	40	40	80
2	11/06/2022	Greenwich	0.118	0.118	30	30	60
3	11/06/2022	Hounslow	0.220	0.220	56	56	112
4	11/06/2022	Richmond upon Thames	0.078	0.078	20	20	40
5	11/06/2022	Hammersmith and Fulham	0.192	0.192	49	49	98
6	11/06/2022	Kensington and Chelsea	0.039	0.039	10	10	20
7	11/06/2022	City of Westminster	0.078	0.078	20	20	40

	date	London Borough	supplier 1 prob	supplier 2 prob	supplier 1 quantity	supplier 2 quantity	Supplier ALL
8	12/06/2022	Camden	0.118	0.118	60	30	90
9	12/06/2022	Ealing	0.157	0.157	80	40	120
10	12/06/2022	Greenwich	0.118	0.118	60	30	90
11	12/06/2022	Hounslow	0.220	0.220	112	56	168
12	12/06/2022	Richmond upon Thames	0.078	0.078	40	20	60
13	12/06/2022	Hammersmith and Fulham	0.192	0.192	98	49	147
14	12/06/2022	Kensington and Chelsea	0.039	0.039	20	10	30
15	12/06/2022	City of Westminster	0.078	0.078	40	20	60

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 [15]:

```
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[["date", "London Borough", "Supplier ALL",\
               r_norm_shop+"1", r_norm_shop+"2", r_norm_shop+"3", \
               "Supply AS Demand Shop 1", "Supply AS Demand Shop 2", \
                                        "Supply AS Demand Shop 3"]]
```

```
Total Supply AS Demand:
Supply AS Demand Shop 1    210
Supply AS Demand Shop 2    315
Supply AS Demand Shop 3    600
dtype: int64
```

Out[15]:

	date	London Borough	Supplier ALL	row Normalised Weight Shop 1	row Normalised Weight Shop 2	row Normalised Weight Shop 3	Supply AS Demand Shop 1	Supply AS Demand Shop 2	Supply AS Demand Shop 3
0	11/06/2022	Camden	60	0.000000	0.000	0.000000	0	0	0
1	11/06/2022	Ealing	80	0.000000	0.000	1.000000	0	0	80
2	11/06/2022	Greenwich	60	0.000000	1.000	0.000000	0	60	0
3	11/06/2022	Hounslow	112	0.000000	0.375	0.625000	0	42	70
4	11/06/2022	Richmond upon Thames	40	1.000000	0.000	0.000000	40	0	0
5	11/06/2022	Hammersmith and Fulham	98	0.285714	0.000	0.714286	28	0	70

	date	London Borough	Supplier ALL	row Normalised Weight Shop 1	row Normalised Weight Shop 2	row Normalised Weight Shop 3	Supply AS Demand Shop 1	Supply AS Demand Shop 2	Supply AS Demand Shop 3
6	11/06/2022	Kensington and Chelsea	20	0.400000	0.600	0.000000	8	12	0
7	11/06/2022	City of Westminster	40	0.200000	0.300	0.500000	8	12	20
8	12/06/2022	Camden	90	0.000000	0.000	0.000000	0	0	0
9	12/06/2022	Ealing	120	0.000000	0.000	1.000000	0	0	120
10	12/06/2022	Greenwich	90	0.000000	1.000	0.000000	0	90	0
11	12/06/2022	Hounslow	168	0.000000	0.375	0.625000	0	63	105
12	12/06/2022	Richmond upon Thames	60	1.000000	0.000	0.000000	60	0	0
13	12/06/2022	Hammersmith and Fulham	147	0.285714	0.000	0.714286	42	0	105
14	12/06/2022	Kensington and Chelsea	30	0.400000	0.600	0.000000	12	18	0
15	12/06/2022	City of Westminster	60	0.200000	0.300	0.500000	12	18	30

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 [9]:

```
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)
```

```
Total Supply AS Demand:
Supply AS Demand Shop 1    210
Supply AS Demand Shop 2    315
Supply AS Demand Shop 3    600
dtype: int64
Available Demand:  {'shop 1': 150, 'shop 2': 315, 'shop 3': 300}
```

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 [10]:

```
# 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"]]
```

Out[10]:

	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
0	11/06/2022	Camden	0	0	0	0.000000	0.000000	0.000000
1	11/06/2022	Ealing	0	0	80	0.000000	0.000000	0.133333
2	11/06/2022	Greenwich	0	60	0	0.000000	0.190476	0.000000
3	11/06/2022	Hounslow	0	42	70	0.000000	0.133333	0.116667
4	11/06/2022	Richmond upon Thames	40	0	0	0.190476	0.000000	0.000000
5	11/06/2022	Hammersmith and Fulham	28	0	70	0.133333	0.000000	0.116667
6	11/06/2022	Kensington and Chelsea	8	12	0	0.038095	0.038095	0.000000
7	11/06/2022	City of Westminster	8	12	20	0.038095	0.038095	0.033333
8	12/06/2022	Camden	0	0	0	0.000000	0.000000	0.000000
9	12/06/2022	Ealing	0	0	120	0.000000	0.000000	0.200000
10	12/06/2022	Greenwich	0	90	0	0.000000	0.285714	0.000000
11	12/06/2022	Hounslow	0	63	105	0.000000	0.200000	0.175000
12	12/06/2022	Richmond upon Thames	60	0	0	0.285714	0.000000	0.000000
13	12/06/2022	Hammersmith and Fulham	42	0	105	0.200000	0.000000	0.175000
14	12/06/2022	Kensington and Chelsea	12	18	0	0.057143	0.057143	0.000000

	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
15	12/06/2022	City of Westminster	12	18	30	0.057143	0.057143	0.050000

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 [11]:

```
# 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"]]
```

```
Avalaible Demand Shop 1:  150
Avalaible Demand Shop 2:  315
Avalaible Demand Shop 3:  300
```

Out[11]:

	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
0	11/06/2022	Camden	0.000000	0.000000	0.000000	0	0	0
1	11/06/2022	Ealing	0.000000	0.000000	0.133333	0	0	40
2	11/06/2022	Greenwich	0.000000	0.190476	0.000000	0	60	0
3	11/06/2022	Hounslow	0.000000	0.133333	0.116667	0	42	35
4	11/06/2022	Richmond upon Thames	0.190476	0.000000	0.000000	29	0	0
5	11/06/2022	Hammersmith and Fulham	0.133333	0.000000	0.116667	20	0	35
6	11/06/2022	Kensington and Chelsea	0.038095	0.038095	0.000000	5	12	0
7	11/06/2022	City of Westminster	0.038095	0.038095	0.033333	5	12	10
8	12/06/2022	Camden	0.000000	0.000000	0.000000	0	0	0
9	12/06/2022	Ealing	0.000000	0.000000	0.200000	0	0	60
10	12/06/2022	Greenwich	0.000000	0.285714	0.000000	0	90	0

	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
11	12/06/2022	Hounslow	0.000000	0.200000	0.175000	0	63	53
12	12/06/2022	Richmond upon Thames	0.285714	0.000000	0.000000	44	0	0
13	12/06/2022	Hammersmith and Fulham	0.200000	0.000000	0.175000	31	0	52
14	12/06/2022	Kensington and Chelsea	0.057143	0.057143	0.000000	8	18	0
15	12/06/2022	City of Westminster	0.057143	0.057143	0.050000	8	18	15

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

In [12]:
```
# 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)
```

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

Out[12]:
```
Final Allocation Shop 1    150
Final Allocation Shop 2    315
Final Allocation Shop 3    300
dtype: int64
```