Supply Chain Analytics

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Coursework

by

Group Beta

Name	URN	Section number	Individual mark	Total mark
Marilia Moniati	6562854	1		
Neha Kahyap	6542949	2		
Amol Dixit	6562752	3		

SURREY BUSINESS SCHOOL

UNIVERSITY OF SURREY
Business Transformation Department

BUSINESS ANALYTICS

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The Banana Supply Chain Company

CONTENTS

1 DATA COLLECTION & SUPPLIER UTILITY FUNCTION

Section leader: Marilia Moniati

1.1 Data Collection

1.1.1 GENERAL APPROACH

In order for us to identify five countries to import bananas from, we took into consideration several factors that will be analysed in the upcoming sections.

Bananas are a challenging product to import because of their "healthy" life period which is quite short and hence, we had to take into consideration speed and distance when it came to choosing suppliers in order for bananas to be well fitted in our production line. Since our plant is 10 miles from Tilbury docks, we aimed to find suppliers from countries around it such as the Netherlands, Germany, France, Belgium and Denmark. These five countries were our initial favourites but after finding data online some of these did not offer as many benefits as other suppliers from countries who were further away. Moreover, we decided to stick to suppliers which we could import products from via ports since it widely known that shipping is the easiest and less costly method of importing products.

After researching on Alibaba.com we narrowed down to nine suppliers from different countries all over the world. Each of these suppliers, had certain characteristics that were analysed and taken into consideration when making the final decision of which suppliers we would be importing from.

1.1.2 DISTANCE TO PLANT AND SHIPPING DURATION

Distance & Travel Time				
Supplier Id	**Country**	**Distance from Plant (miles)**	**Distance from plant (km)**	**Shipping Duration**
1	South Africa	621.06418	993.412	5
2	Netherlands	301.14734	478.556	7
3	Belgium	196.42636	310.024	10
4	France	2653.34166	4264.044	11
5	Denmark	1082.52696	1736.064	8
6	Educador	8666.16716	13940.744	18
7	India	8678.82574	13961.116	10
8	Canada	3751.18578	6030.852	3
9	Philippines	11538.51404	18563.336	2

Figure 1

The above figure shows our nine possible supplier choices and their distance from our plant in Tilbury docks in miles and kilometers. In order to calculate the distance of each supplier from our plant, we considered the port where products would be exported from according to Alibaba.com and used an online port distance calculator ADD LINK to calculate each supplier's distance from our plant. We then added 10 miles to the final answer since our plant is 10 miles away from Tilbury Docks which is the final port destination. It was essential to calculate the distance from our plant in kilometers too since some of the possible supplier countries use kilometers as their basic metric system. As shown in Figure 1, shipping duration was taken from the details that each supplier provided on Alibaba.com.

1.1.3 FREIGHT RATES

A freight rate is the price at which a certain product is delivered from the starting port to the end port. This price fluctuates according to the product, the way of transport, in our case via port, the weight of the container which the product is in and the distance between the ports. In order to calculate the freight rate we used the online freight calculator https://www.worldfreightrates.com/en/freight as suggested by Dr Wolfgang in this module's lectures. The online freight rate calculator, asked us to input the origin port and the destination port, the area which our product belonged to which in our case is agriculture, as well as choose the way of transport of good which in our case is via ships and containerised. Moreover it was essential at this point of the analysis to decide on which containers we would be using for transport. Since 20ft containers are too small and are not practical for large quantity transportation we chose to transport our product using 40 ft full truck load (FTL). The reason behind choosing a FTL container to a weight of loose cargo is that FTL containers usually have lower freight rates. Finally, the calculated freight rate did not take into consideration insurance.

Freight Rates		
Supplier ID	**Country**	**Freight Rate (Dollars)**
1	South Africa	$1,914.99 - $2,116.57
2	Netherlands	$1,896.59 - $2,096.23
3	Belgium	$1,933.39 - $2,136.90
4	France	$1,934.03 - $2,137.61
5	Denmark	$1,933.39 - $2,136.90
6	Educador	$7,828.05 - $8,652.06
7	India	$3,951.42 - $4,367.36
8	Canada	$2,205.96 - $2,438.17
9	Philippines	$2,814.79 - $3,111.08

Figure 2

Figure 2 shows the format in which the online freight rate calculator gave us the freight rated for our nine possible suppliers. In order for data concerning freight rated to be considered in the Supplier Utility Function we needed to edit our freight rates in pounds per 100 miles and euros per 100 kilometers. In order to achieve this, we calculated an average of this ratio that the online freight rate calculator gave us and then converted this number from dollars to euros and then to pounds. So we could convert this average to freight rate in pound per 100 miles and euros per 100 kilometers we divided the average freight rate number by 26.11, which is the maximum refrigerated container load in tonnes according to https://elarum.com/info/references/container-dimensions/, multiplied it by 100 and then divided by the distance to plant in miles and in kilometers accordingly. Figure 3 shows these calculations for each supplier.

Freight Rates			
Supplier ID	**Country**	**Freight rate (in pounds per ton per 100 miles)**	**Freight rate (in Euros per ton per 100 km**
1	South Africa	£ 9.70	€6.99
2	Netherlands	£ 13.28	€9.64
3	Belgium	£ 30.95	€22.63
4	France	£ 2.29	€1.65
5	Denmark	£ 5.62	€4.04
6	Educador	£ 2.84	€2.04
7	India	£ 1.43	€1.03
8	Canada	£ 1.85	€1.33
9	Philippines	£ 0.77	€0.55

Figure 3

1.1.4 COMMODITY VALUE

The commodity value of a good is its free market intrinsic value. This value will be reflected by its price. In order to calculate the commodity value of each of our suppliers, we took the price of each product per kilogram and multiplied it by, 25462.47 which we got by multiplying the maximum container load with the amount of tonnes we are going to be importing. This multiplication gave us the commodity value of each product. The commodity value would later on be used in calculating the total cost of bananas per each container. Figure 4 clearly shows the price per kilogram as well as the calculated commodity value of product.

Commodity Values			
Supplier ID	**Country**	**Price £/kg**	**Commodity value of product (£) - FTL**
1	South Africa	0.58	£ 14,768.23
2	Netherlands	0.63	£ 16,041.36
3	Belgium	0.48	£ 12,221.99
4	France	0.62	£ 15,786.73
5	Denmark	0.29	£ 7,384.12
6	Educador	0.8	£ 20,369.98
7	India	0.54	£ 13,749.73
8	Canada	0.62	£ 15,786.73
9	Philippines	0.54	£ 13,749.73
		Avg in GBP	**£ 14,428.73**

Figure 4

1.1.5 COST OF BANANAS FOR EACH SUPPLIER PER TON AND PER CONTAINER

In order to calculate the total cost of bananas from each supplier we firstly calculated the total cost of the product per container by adding the commodity value with the freight rate in pounds per ton per 100 miles. This calculation gave us the total cost per container. We then calculated the total cost per ton by dividing the total cost per container by 26.11 which is the tonnes that fit into one container.

Total Cost of Bananas					
Supplier ID	**Comm. Value**	**Freight Rate**	**Total Cost Per Container**	**Total Cost Per Ton**	**Total Cost Per Cwt**
1	£ 14,768.23	£ 1,572.31	£ 16,340.54	£ 625.83	£ 32.58
2	£ 16,041.36	£ 1,044.05	£ 17,085.41	£ 654.36	£ 34.06
3	£ 12,221.99	£ 1,587.41	£ 13,809.40	£ 528.89	£ 27.53
4	£ 15,786.73	£ 1,587.94	£ 17,374.67	£ 665.44	£ 34.64
5	£ 7,384.12	£ 1,587.41	£ 8,971.53	£ 343.61	£ 17.89
6	£ 20,369.98	£ 6,427.24	£ 26,797.22	£ 1,026.32	£ 53.42
7	£ 13,749.73	£ 3,244.32	£ 16,994.06	£ 650.86	£ 33.88
8	£ 15,786.73	£ 1,811.21	£ 17,597.94	£ 673.99	£ 35.08
9	£ 13,749.73	£ 2,311.09	£ 16,060.82	£ 615.12	£ 32.02

Figure 5

1.2 Supplier Utility Function and Quantity Shipped Per Supplier Per Month

1.2.1 SUPPLIER UTILITY FUNCTION

First Step:

In order to shortlist five of the nine suppliers we have analysed above, we used a Supplier Utility Function to compare the benefits of each of our suppliers. We had to decide on what the order winners will be before starting our evaluation . Our order winners were quality, cost and delivery time. Below you can find a table that states all of the above according to each supplier.

Supplier ID	Grade	Country of Origin	Distance from Plant in miles	Cost of Bananas per Ton in GBP
1	A	South Africa	621.06418	£ 625.83
2	AA	Netherlands	301.14734	£ 654.36
3	A	Belgium	196.42636	£ 528.89
4	A	France	2653.34166	£ 665.44
5	A	Denmark	1082.52696	£ 343.61
6	AAA	Educador	8666.16716	£ 1,026.32
7	A	India	8678.82574	£ 650.86
8	AA+	Canada	3751.18578	£ 673.99
9	A	Philippines	11538.51404	£ 615.12

Figure 6

The above fields correspond to our three order winners. Distance from Plants has to do with Delivery Time, cost of bananas per Ton is associated with Cost and grade as well as country of origin are associated with Quality. We considered adding shipping duration in our process to but avoided it because of unnecessary complexity since distance from Plant is analogical to shipping duration.

Second Step:

In order to continue with the supplier utility function, we needed to rank the grade of the bananas we will be importing. According to our data we split the varieties as follows:

- Grade AAA: 1
- Grade AA+: 0.75
- Grade AA: 0.5
- Grade A: 0.25

We then went on and ranked the country of origin according to the quality of bananas each country produces with 2% being the worst quality and 27% being the best.

- South Africa: 0.16
- Netherlands: 0.21
- Belgium: 0.27
- France: 0.08
- Denmark: 0.12
- Educador: 0.05
- India: 0.03
- Canada: 0.06

- Philippines:0.02

Finally, we also had another field, Distant from our plant, which was calculated by dividing the distance of each supplier by the maximum distance of all nine suppliers.

The figure below show the three fields mentioned above according to each supplier.

Supplier ID	Grade -p	Country of origin -p	Distance from our plant -p
1	0.25	0.16	0.946174683
2	0.5	0.21	0.973900683
3	0.25	0.27	0.98297646
4	0.25	0.08	0.770044769
5	0.25	0.12	0.906181424
6	1	0.05	0.248935597
7	0.25	0.03	0.247838525
8	0.75	0.06	0.674898712
9	0.25	0.02	0

Figure 7

Step 3:

In the process of obtaining the five suppliers, we had to prioritise which field is of highest importance. We did this using the Weighted Decision Strategy and decided on Grade that has to do with Quality is the utility of highest importance followed by the Distance from our plant that had to do with Delivery Time. Lastly we believe that country is the utility of least importance. In order to distinguish between the three we used the number 1,2 and 3 as weights, with 1 being the least important weight and then multiplied the values in the table with the corresponding weight.

Finally benefits were calculated for all nine suppliers by averaging the three utilities.

	3	*1*	*2*	
Supplier ID	**Grade**	**Country**	**Distance from our plant**	**Benefits**
1	0.75	0.16	1.89	0.93
2	1.5	0.21	1.95	1.22
3	0.75	0.27	1.97	1.00
4	0.75	0.08	1.54	0.79
5	0.75	0.12	1.81	0.89
6	3	0.05	0.50	1.18
7	0.75	0.03	0.50	0.43
8	2.25	0.06	1.35	1.22
9	0.75	0.02	0.00	0.26

Figure 8

Step 4:

During the final step of the Supplier Utility Function we put together a table with the supplier ID, benefits and total cost of bananas per ton and we sorted this table in descending order according to benefits. Figure 9 clearly shows this table.

Supplier ID	Benefits	Total Cost Bananas/ton
2	1.22	£ 654.36
8	1.22	£ 673.99
6	1.18	£ 1,026.32
3	1	£ 528.89
1	0.93	£ 625.83
5	0.89	£ 343.61
4	0.79	£ 665.44
7	0.43	£ 650.86
9	0.26	£ 615.12

Figure 9

To make the final decision, we executed a Benefits VS Cost Analysis so we could ensure that the suppliers we chose are the most suitable.

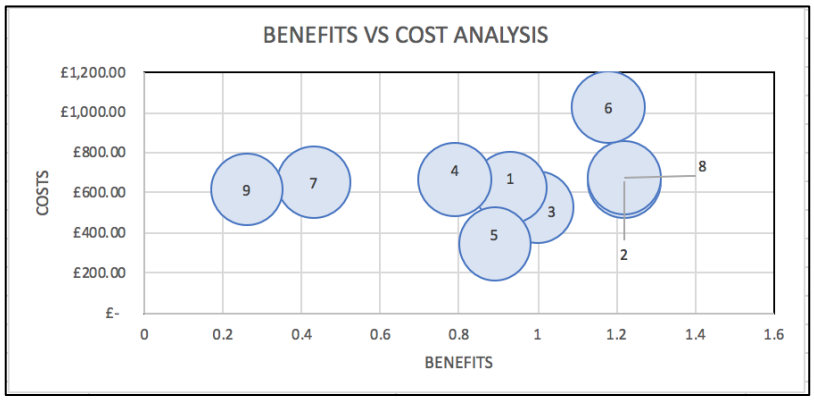

Figure 10

As clearly shown in Figure 10 we chose suppliers 2,8,6,3 and 1. Figure 11 shown the final suppliers and their characteristics.

Supplier ID	Country	Port	Variety	Grade	Quantity Availability for shipment per	Distance from Plant	Total Cost of Bananas per ton (£)
1	South Africa	Hamburg	Cavendish	A	250.00	621.06	£ 625.83
2	Netherlands	Rotterdam	Cavendish	AA	5000.00	301.15	£ 654.36
3	Belgium	Antwerp	Cavendish	A	100.00	196.43	£ 528.89
6	Educador	Guayaquil	Cavendish	AAA	2400.00	8666.17	£1,026.32
8	Canada	Montreal	Cavendish	AA+	50000.00	3751.19	£ 673.99

Figure 11

1.2.2 QUANTITY SHIPPED PER SUPPLIER PER MONTH

Since we decided on our five, we used these data amongst the data that has to do with the recipes of the products we are producing and decided on the total required supply per month. Our company will be producing Banana Chips and Dried Bananas.

We decided to produce 700000 bags of Banana Chips and 30000 bags of Dried Banana Slices per year. This estimation is based on information found on the Internet from our main competitors in the UK. However, at the beginning of our project, we thought we would only manage to produce Banana Chips but later on discovered that we had excess raw materials and we would be able to produce another product which is Dried Banana Slices. We chose to produce Dried Banana Slices as a second product because of the fact that the process of producing the finished good would be quite similar. According to the above, we decided in relation to Section 2, Production Mix, that our total required supply is **300 tons of bananas per month.**

FINAL QUANTITY SUPPLIED PER SUPPLIER MONTHLY

We based our final decision based on how much bananas we will be importing from each supplier per month, on the Total Cost of Bananas per ton that we previously calculated as shown in sections above.

Supplier Country	Supply per Month	Cost Ranking	Available Supply/Month	Total Cost of Bananas per Ton	Total Monthly Cost of Supply Quantity
1 – South Africa	60	2	60	£ 625.83	£ 37,549.8
2 – Netherlands	100	3	100	£ 654.36	£ 65,436
3 – Belgium	20	1	20	£ 528.89	£ 10,577.8
6 – Educador	20	5	80	£ 1,026.3	£ 20,526
8 – Canada	100	4	100	£ 673.99	£ 67,399
Demand	**300 tons**				**£ 201,488.6**

2 BREAK-EVEN POINT & PRODUCTION MIX

Section leader: Neha Kashyap

2.1 BREAK-EVEN POINT

The company will purchase banana from the above identified 5 suppliers of South Africa, Netherlands, Belgium, Educador and Canada. As per the information provided from part1 the average total cost of raw material including transportation is £701 per ton. The supply per month of banana is 300 tons for Fried Banana chips production. As per the recipe the company total production of Fried Banana chips is 100 tons per month (1000000 bags of 100g chips). In order to calculate the break-even point, the cost has been derived as the average raw material cost for 300 tons of raw material (£701*300 per month) from the five suppliers, including the transportation cost. Cv (variable cost) is £2.14 per 100g of banana chips bags. The company will sell banana chips to supermarkets for a competitive price of £3 per 100g bags. The typical products found in market offered by competitors are fried banana chips and dried banana slices and prices of products vary from £2.5 - £3.50 per 100g of bags. The ratio of raw material to processed product is assumed as 3:1 based on the market research and competition information. The staff's salaries consist of 25 employee and 5 factory managers, cost for premises and other fixed costs for the factory is derived as below.

Fig 1- Fixed cost calculation

Fixed cost	Amount	Description
c_{f1} =	£93,000.00	Fixed inventory cost
c_{f2} =	£220,000.00	Fixed factory cost
c_{f3} =	£80,017.00	Fixed labour cost
Cf total =	£393,017.00	

The uncertainty of the estimations was calculated on cost and price and the cost of raw material is £701/per ton on an average as per part 1 calculation.

- The break-even point was calculated based on the information as below, as the company is making profit further expansion of product line is feasible option for the company using the same raw material. Though the initial production capacity is estimated as 100 tons of processed product, b

volume	cost	revenue
0.00 bags	£393,017.00	£0.00
913,994.00 bags	£2,348,964.16	£2,741,982.00
456,997.00 bags	£1,370,990.58	£1,370,991.00

ess can optimise the resource in new production line.

Fig 2 - Revenue and cost calculation for the volume of production

	Total Production	100.00 tons/month	Unit is 100 g bag each = 1000000 bags
Essential information (per month)			
	Variable	Banana Chips	Description
	c_f =	£393,017.00	Total fixed costs
	c_v =	£2.14	Variable cost per unit
	p =	£3.00	Price per unit
	v_c =	1,000,000.00 bags	Current volume
Finances - current (per month)			
	R_c =	£3,000,000.00	current revenues
	C_c =	£2,533,017.00	current costs
	P_c =	£466,983.00	profit/loss
Break-even (per month)			
	V_{BE} =	456,997.00	Break-even volume
	R_{BE} =	£1,370,991.00	Break-even revenues
	C_{BE} =	£1,370,990.58	Break-even costs
	P_{BE} =	£ 0	Break-even profit
	Fixed cost	Total production	Description
	c_{f1} =	£93,000.00	Fixed inventory cost
	c_{f2} =	£220,000.00	Fixed factory cost
	c_{f3} =	£80,017.00	Fixed labour cost
	Cf total =	£393,017.00	

Fig 3- Information about the production

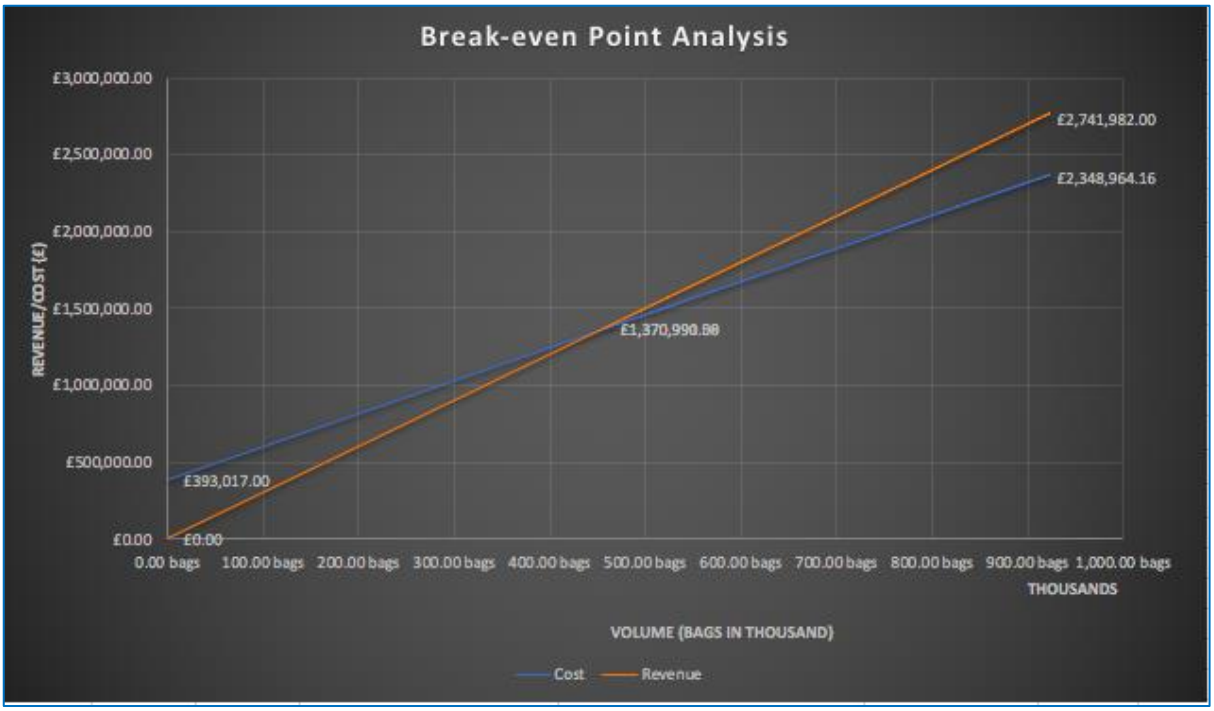

Fig 4 - Break-even point analysis for the 100 ton of total production

- **Cost sensitivity analysis**

volume	cost	cost - 10%	cost +10%	revenue
-	£393,017.00	£353,715.30	£432,318.70	£0.00
329,344	£1,097,812.85	£988,031.56	£1,207,594.13	£988,031.56
669,224	£1,825,156.35	£1,642,640.71	£2,007,671.98	£2,007,671.98
1,338,448	£3,257,295.69	£2,931,566.12	£3,583,025.26	£4,015,343.96

Fig 5 - Table for cost sensitivity analysis

Cost sensitivity can be calculated as per the table above where the increase in cost by 10% and decrease in cost by 10% can be reflected in the volume of production. The feasible reason has been shown below in the chart

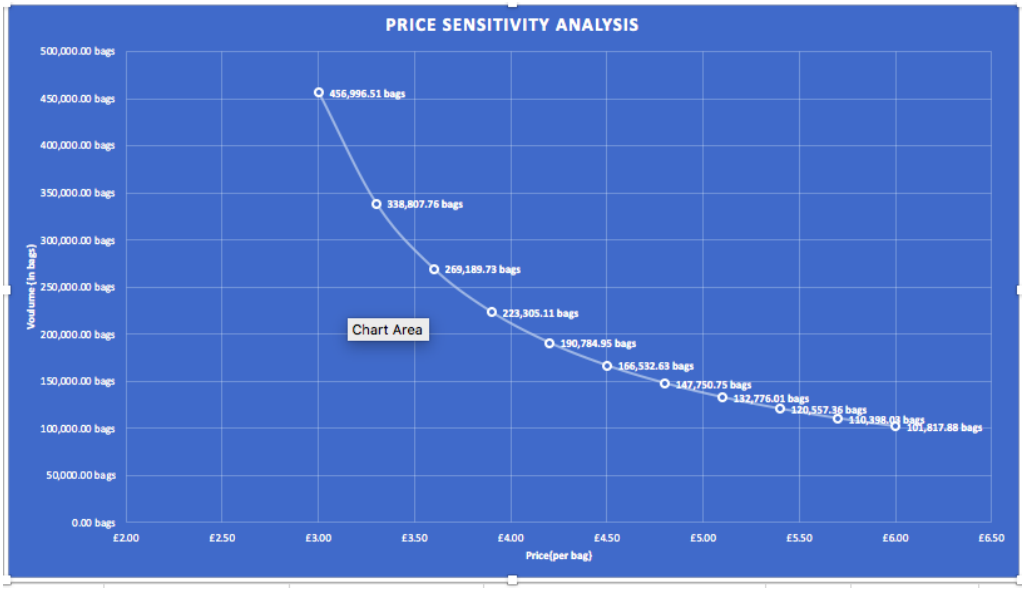

Fig 6 - Cost sensitivity chart

- Price sensitivity analysis below is calculated to see how the breakeven point changes with 10%-100% increase in price.

increase	price per unit	BE Point Volume
0%	£3.00	456,996.51 bags
10%	£3.30	338,807.76 bags
20%	£3.60	269,189.73 bags
30%	£3.90	223,305.11 bags
40%	£4.20	190,784.95 bags
50%	£4.50	166,532.63 bags
60%	£4.80	147,750.75 bags
70%	£5.10	132,776.01 bags
80%	£5.40	120,557.36 bags
90%	£5.70	110,398.03 bags
100%	£6.00	101,817.88 bags

Fig 7 - Table of price sensitivity calculation

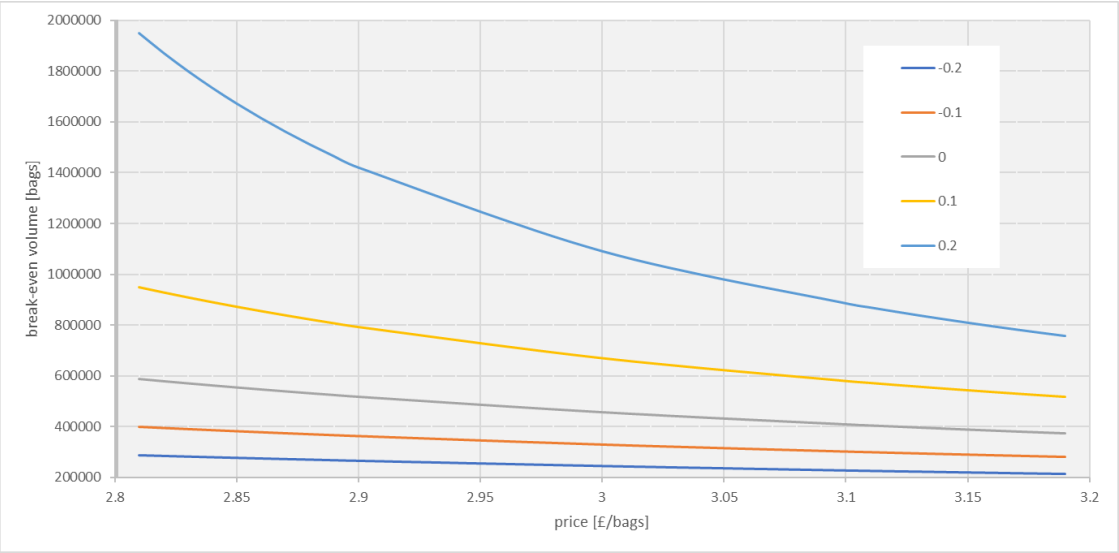

Fig 8 - Graph showing the change in BE volume with the change in price

- Cost relationships is also shown below with the respective change in the Break-even points.

Fig 9 - Table of what -if analysis

Price ↑↓	Cost ↑↓		Break-even Points		
	-20%	-10%	0%	10%	20%
£2.81	286,351 bags	400,130 bags	586,593 bags	948,067 bags	1,948,845 bags
£2.82	283,767 bags	395,655 bags	577,966 bags	927,723 bags	1,871,510 bags
£2.83	281,229 bags	391,278 bags	569,590 bags	908,233 bags	1,800,078 bags
£2.84	278,735 bags	386,997 bags	561,453 bags	889,545 bags	1,733,899 bags
£2.85	276,286 bags	382,809 bags	553,545 bags	871,610 bags	1,672,413 bags
£2.86	273,879 bags	378,710 bags	545,857 bags	854,385 bags	1,615,138 bags
£2.87	271,514 bags	374,698 bags	538,379 bags	837,827 bags	1,561,657 bags
£2.88	269,190 bags	370,771 bags	531,104 bags	821,899 bags	1,511,604 bags
£2.89	266,905 bags	366,925 bags	524,023 bags	806,565 bags	1,464,660 bags
£2.90	264,658 bags	363,157 bags	517,128 bags	791,792 bags	1,420,543 bags
£3.00	244,110 bags	329,344 bags	**456,997 bags**	669,224 bags	1,091,714 bags
£3.10	226,523 bags	301,291 bags	409,393 bags	579,516 bags	886,505 bags
£3.11	224,902 bags	298,746 bags	405,172 bags	571,850 bags	870,148 bags
£3.12	223,305 bags	296,244 bags	401,038 bags	564,385 bags	854,385 bags
£3.13	221,730 bags	293,783 bags	396,987 bags	557,112 bags	839,182 bags
£3.14	220,178 bags	291,364 bags	393,017 bags	550,024 bags	824,511 bags
£3.15	218,646 bags	288,983 bags	389,126 bags	543,114 bags	810,344 bags
£3.16	217,136 bags	286,641 bags	385,311 bags	536,376 bags	796,656 bags
£3.17	215,647 bags	284,337 bags	381,570 bags	529,802 bags	783,423 bags
£3.18	214,178 bags	282,070 bags	377,901 bags	523,388 bags	770,622 bags
£3.19	212,729 bags	279,838 bags	374,302 bags	517,128 bags	758,232 bags

Fig 10 - Table of what if analysis calculation based on break even volume and price changes.

Based on the above calculation and analysis, its recommended that the company has capacity to add more product to their production line. The break-even volume for banana chips is 456997 bags and by producing 1000000 bags of fried banana chips the company has a profit of £466983 per month. The company is advised to extend the business by bringing new product into the market. For the optimisation of the raw material and

the resources available, along with Banana chips, Dried banana slices could be added as a new product, which could be a premium product and required same amount of resources and equipment. The profit company is earning can be spend on brand awareness and in procurement of quality raw material from the supplier.

2.2 PRODUCTION MIX

The company has assessed the best production mix for a range of possible products that can be produced for optimal production and use of available resources with constraints. Also, the company's focus is to produce a premium quality product by optimising the available resources. Assuming that the production of fried banana chips and dried banana chips use the same raw material, where the total production rates of 100 tons of combined is calculated based on the above production. The number of working-days per month is 26 day for 8 hrs and so having total of 5200 hours. The demand limit in tons of finished goods that have to be produced per month as below

Calculation of hours needed per finished product			
	Fried Banana Chips bag	Dried banana slices bag	**Total**
Demand limit in finished products (per month)	700000 bags	300000 bags	
Hours of labour (60:40)	2080	3120	**5200 hours**
Hours per finished product	0.003 hours	0.01 hours	

Fig - 11. Hours of production per month for each product based on the recipe

The agreed supply of raw material on a monthly basis is 300 tons. Each product sales prices are as below

Additional information	**Column1**	**Column2**
	Fried Banana Chips	Dried banana slices
Demand limit in finished products (per month)	70000 bags	30000 bags
Selling Price	GBP 3.00	GBP 3.30

Fig -12 Demand limit and selling price of each product.

The raw material that can be used for the finished goods is 95%. The minimum tonnage that has to be manufactured for each product, e.g. due to sales agreements and the required raw material are as below:-

Constraints	Daily	Monthly
No of working days per month		26 days
Hours of labour	200 hours	**5200 hours**
Raw material received	9.86 tons	300.00 tons
Raw material that can be used	95%	95%
Available raw material	9.37 tons	**285.00 tons**
Minimum production of Fried Banana Chips (due to sales agreements with Distributors)		500000 bags
Minimum production of Dried Banana Slices (due to sales agreements with Distributors)		200000 bags

Fig 13- Constraint for the production considered to find the optimal production of each product

- The tonnage of finished fried banana chips is 977896 bags and dried banana slices are 226629 bags for maximum profit and keeping the constraints into consideration. Excel solver was used for the below analysis.

Resource Requirements and Profits	Fried Banana Chips bag	Dried banana slices ba
Quantity to be produced	**977896 bags**	**226629 bags**
Labour	0.003 hours	0.010 hours
Ingredients (Banana)	0.000233 tons	0.000251 tons
Profit	GBP 2.14	GBP 3.13
Total Profit	GBP 2092697.44	GBP 709348.77

Fig 14- Optimal production mix of the 2 products to maximum profit considering the available constraints

- Revenue and profit were calculated below based in the production mix

Monthly figures based on Optimal Solution	Fried Banana Chips	Dried banana slices	Total
Required Raw Material	228.1 tons	56.9 tons	**285.0 tons**
Finished goods			
Produced quantities as per optimal solution	977896 bags	226629 bags	
Weight per item	0.1 kg	0.1 kg	
Total weight of finished goods	**97789.6 kg**	**22662.9 kg**	
Revenue	GBP 2933688.00	GBP 747875.70	**GBP 3681563.70**
Profit	GBP 2092697.44	GBP 709348.77	**GBP 2802046.21**

Fig 15 - Monthly figures based on the optimal solution

- Data solver in excel was used to reach the optimal calculation value of the production mix.

3 DISTRIBUTION NETWORK & FACILITY LOCATIONS

Section leader: Amol Dixit

3.1 DISTRIBUTION NETWORK

From the information provided in Section 1 and 2, the plant near Tilbury, UK is producing 100 tonnes of products per month. Three more plants are considered to be in economically stable and technologically advanced cities (Berlin, Madrid and Copenhagen). These plants and their productions are shown in table below:

Volume	Supply Nodes	tons/month
120% of Tilbury, UK	Berlin	120
90% of Tilbury, UK	Madrid	90
130% of Tilbury, UK	Copenhagen	130
	Total Supply	**340**

Table 3.1: Supply Nodes and their capacities

The Demand nodes or Distribution Centres are 10 country capitals chosen across the continent of Europe, and the supply is distributed between these on the basis of their relative populations as shown in Table 3.2. Detailed description is present in Table 3.3:

Distribution Centre	Demand (tons/month)
Lisbon	6.85
Moscow	169.38
Warsaw	23.69
Helsinki	8.56
Brussels	16.40
Paris	28.99
Oslo	9.12
Stockholm	13.03
Rome	38.70

Vienna	25.30
Total	**340**

Table 3.2: Demand Distribution

3.1.1 Supply and Demand Information

Supply

The three more plants selected are based in the countries that lead in exports, technology and also have demand for bananas and its products within and around their area. Also, relative locations were taken into account so as to ensure that largest area is spanned by them. Future prospects and opportunities for growth were also a factor in their choice.

The supply quantity of 100 tons of banana products per month from previous section is from the UK plant. Thus, the new plants in Berlin, Madrid, and Copenhagen will have production outputs as shown in Table 3.1

Demand

The demand quantities in the selected European cities have then derived by the percentage of city population to the total population in the 10 cities.

$$supply = TotalSupply * \frac{PopulationOfCity}{SumPopulationOfAllCities}$$

The population in the selected cities and their relative and absolute demand for the products is shown in below Table 3.3

S.No	Distribution Centres	Population	City Population / Total Population	%of Total Population	Demand (tons/month)
1	Lisbon	505,526	0.020136379	2.01	6.846368727
2	Moscow	12,506,468	0.498164238	49.82	169.375841
3	Warsaw	1,748,916	0.069663746	6.97	23.68567355
4	Helsinki	631,695	0.025162009	2.52	8.555083009
5	Brussels	1,211,035	0.048238586	4.82	16.40111913

6	Paris	2,140,526	0.085262562	8.53	28.98927111
7	Oslo	673,469	0.026825973	2.68	9.120830779
8	Stockholm	962,154	0.038325026	3.83	13.03050893
9	Rome	2,857,321	0.113814319	11.38	38.69686849
10	Vienna	1,868,000	0.074407163	7.44	25.29843526
Total		**25,105,110**	**1**	**100**	**340**

Table 3.3: Demand at Distribution Centres

3.1.2 DISTANCE AND COST MATRIX

The distance and cost matrix have been created as shown in Table 3.4 and Table 3.5, respectively. The cost has been calculated by the distance of transporting by truck at the rate of €2.29 per ton per 100km (Garn, W. 2019).

to/from	Berlin	Madrid	Copenhagen
Lisbon	2781 km	628 km	2961 km
Moscow	1819 km	4096 km	2256 km
Warsaw	575 km	2852 km	1011 km
Helsinki	1633 km	3911 km	1132 km
Brussels	764 km	1580 km	919 km
Paris	1068 km	1270 km	1223 km
Oslo	1029 km	2961 km	603 km
Stockholm	1083 km	3308 km	657 km
Rome	1501 km	1957 km	1901 km
Vienna	680 km	2396 km	1114 km

Table 3.4: Distance Matrix

Source: https://www.searates.com/reference/portdistance/

Cost per ton	Berlin	Madrid	Copenhagen
Lisbon	€ 63.68	€ 14.38	€ 67.81
Moscow	€ 41.66	€ 93.80	€ 51.66
Warsaw	€ 13.17	€ 65.31	€ 23.15
Helsinki	€ 37.40	€ 89.56	€ 25.92
Brussels	€ 17.50	€ 36.18	€ 21.05
Paris	€ 24.46	€ 29.08	€ 28.01

Oslo	€ 23.56	€ 67.81	€ 13.81
Stockholm	€ 24.80	€ 75.75	€ 15.05
Rome	€ 34.37	€ 44.82	€ 43.53
Vienna	€ 15.57	€ 54.87	€ 25.51

Table 3.5: Cost Matrix

3.1.3 TRANSPORTATION NETWORKS

The objective is to minimise the transportation cost with the decision variables of cost spent and quantity delivered in every pairs of nodes. The constraints are identified with the limitation of supply quantities and the requirement of demand quantities. Applying this information to Solver add-in Ms Excel, the results have been calculated as follows:

Objective: Minimise the total transportation cost = **€ 13038**

Decision Variables: Quantities from Supply Nodes to Distribution Centres

to/from	Berlin	Madrid	Copenhagen	Received	Total Demand
Lisbon	0.00	6.85	0.00	6.85	6.85
Moscow	120.00	0.00	49.38	169.38	169.38
Warsaw	0.00	0.00	23.69	23.69	23.69
Helsinki	0.00	0.00	8.56	8.56	8.56
Brussels	0.00	0.00	16.40	16.40	16.40
Paris	0.00	28.99	0.00	28.99	28.99
Oslo	0.00	0.00	9.12	9.12	9.12
Stockholm	0.00	0.00	13.03	13.03	13.03
Rome	0.00	28.87	9.83	38.70	38.70
Vienna	0.00	25.30	0.00	25.30	25.30
Supplied	120	90	130	340\340	
Total Supply	120	90	130		340\340

Table 3.6: Decision Matrix

Constraints: (i) Supply

Supply Nodes	Maximum Supply (tons/month)
Berlin	120
Madrid	90
Copenhagen	130
Total Supply	**340**

Table 3.7: Supply Constraints

(ii) Demand

Demand Nodes	Maximum Demand (tons/month)
Lisbon	6.85
Moscow	169.38
Warsaw	23.69
Helsinki	8.56
Brussels	16.40
Paris	28.99
Oslo	9.12
Stockholm	13.03
Rome	38.70
Vienna	25.30
Total Demand	**340**

Table 3.8: Demand Constraints

3.2 FACILITY LOCATIONS

The company is considering introducing three additional warehouses to supply to the 10 Distribution Centres. To find their locations Kruskal's algorithm is employed to find three clusters, and the location of the warehouse is suggested as the centroid of the cluster by using the Centre of Gravity method.

3.2.1 MINIMUM SPANNING TREE (R APPLICATION)

Plotting location of 10 Distribution Centres and calculate the distances between them using R as shown in Figure 3.1 and 3.2

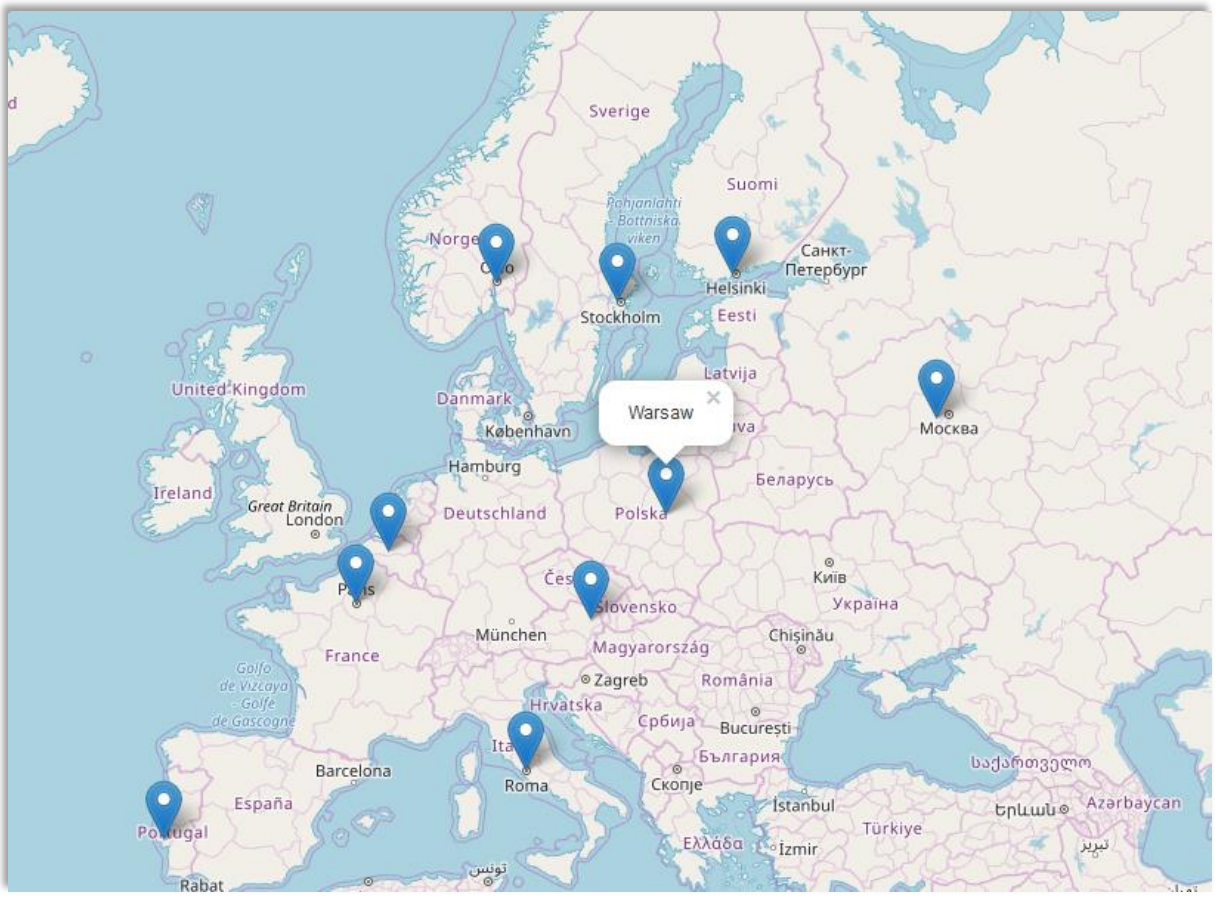

Figure 3.1: Pinned Locations of the 10 Distribution Centres

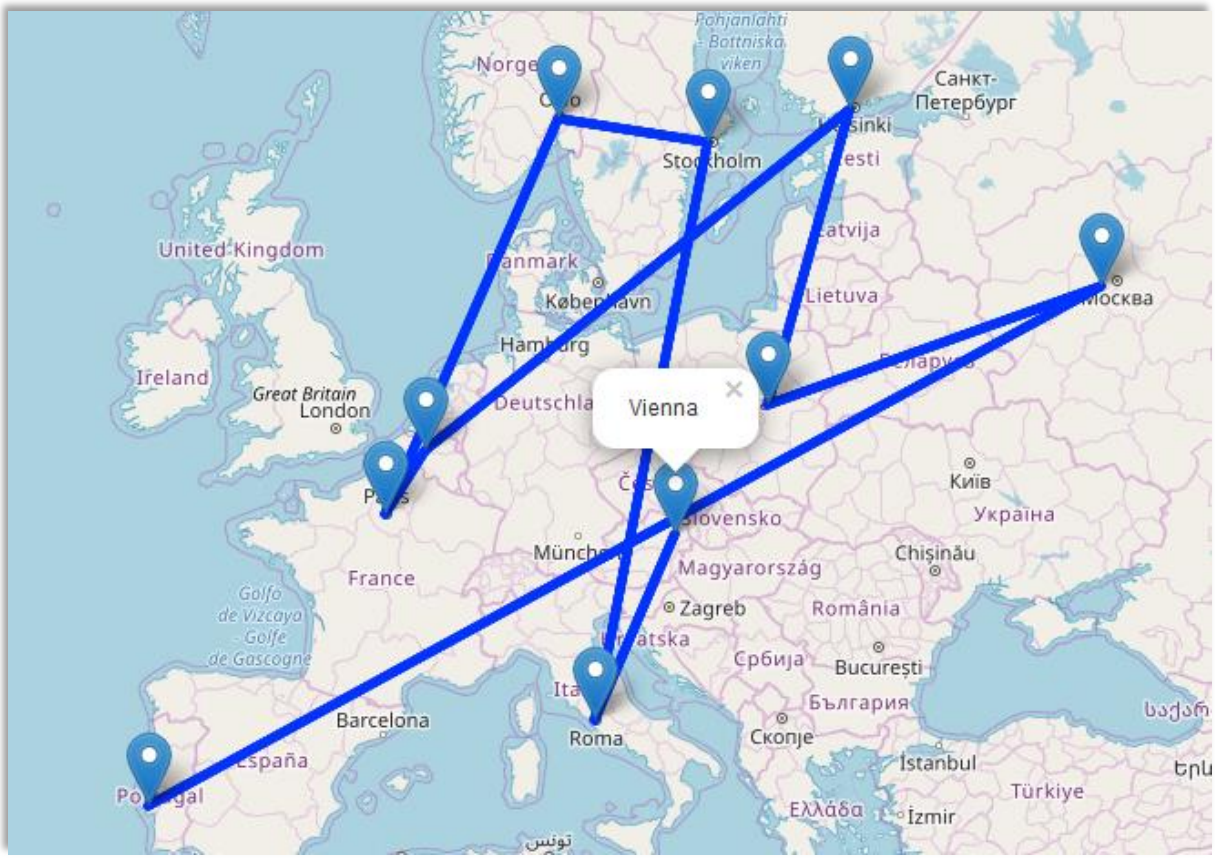

Figure 3.2: Distribution Centres connected arbitrarily

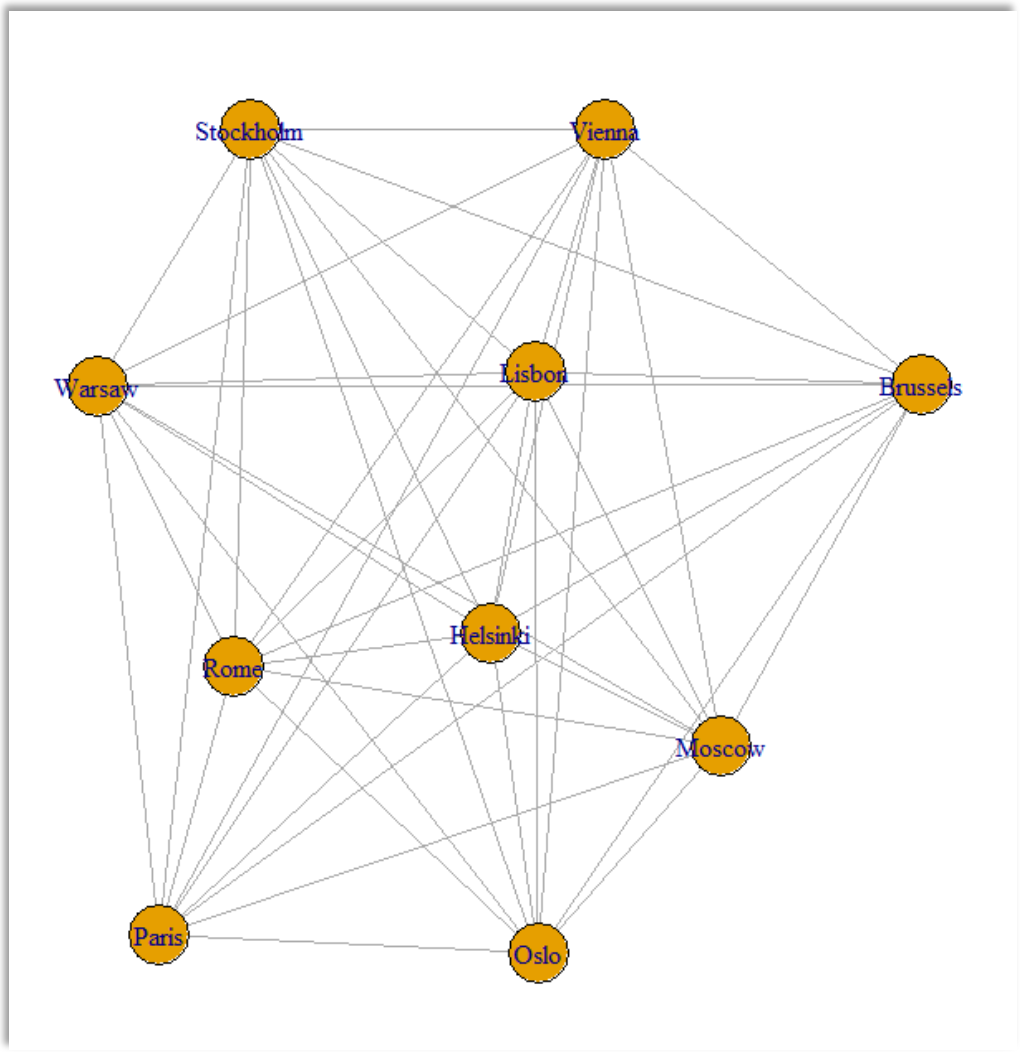

Figure 3.3: Network Structure for the Distribution Centres

Now a Minimum Spanning Tree (MST) I generated by applying Kruskal's Algorithm. The tabular results are displayed in Figure 3.4, giving the distance of **6436 km** in total.

```
-   Minimum Cost Spanning Tree
-    Algorithm: Kruskal
-    Stages:  26 | Time:  0 |
-    ----------------------------
-         ept1     ept2    weight
-            5        6       261
-            4        8       398
-            7        8       411
-            3       10       551
-            9       10       764
-            3        8       811
-            2        4       875
-            5       10       916
-            1        6      1449
-    ----------------------------
-                      Total = 6436
```

Figure 3.4: Minimum Spanning Tree (tabular form) by Kruskal's Algorithm

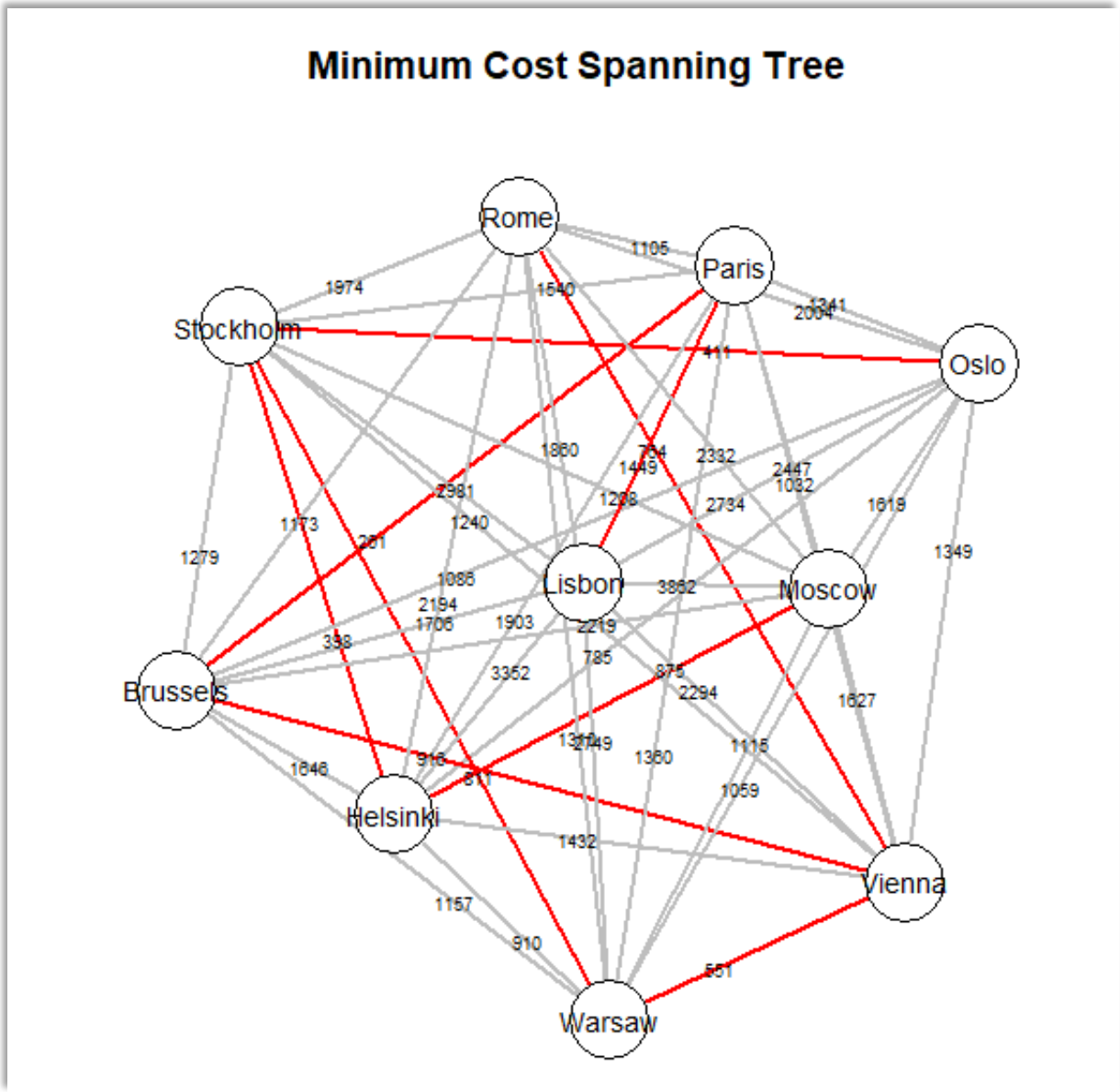

Figure 3.5: Minimum Spanning Tree by Kruskal's Algorithm

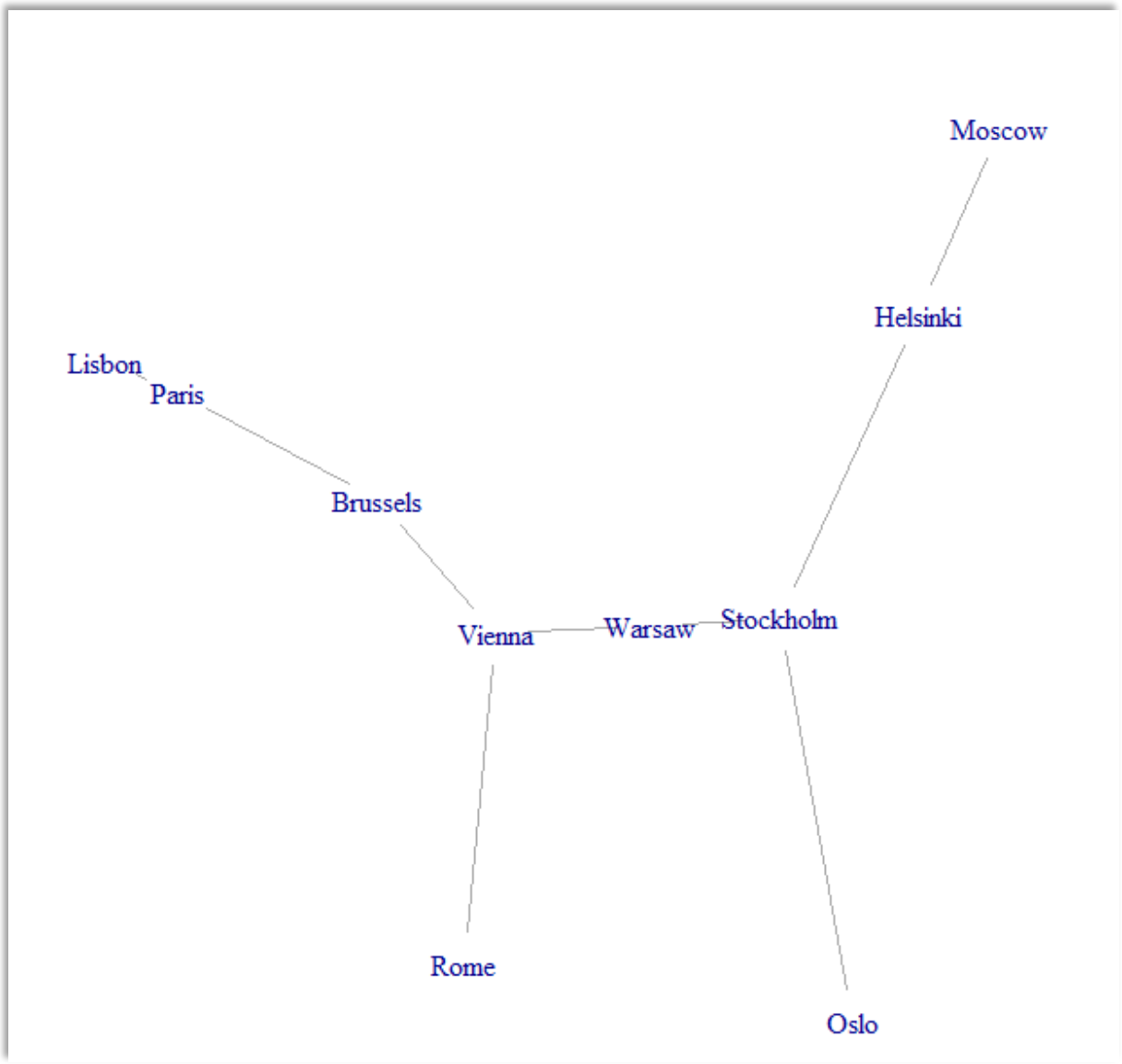

Figure 3.6(i): Minimum Spanning Tree by Kruskal's Algorithm

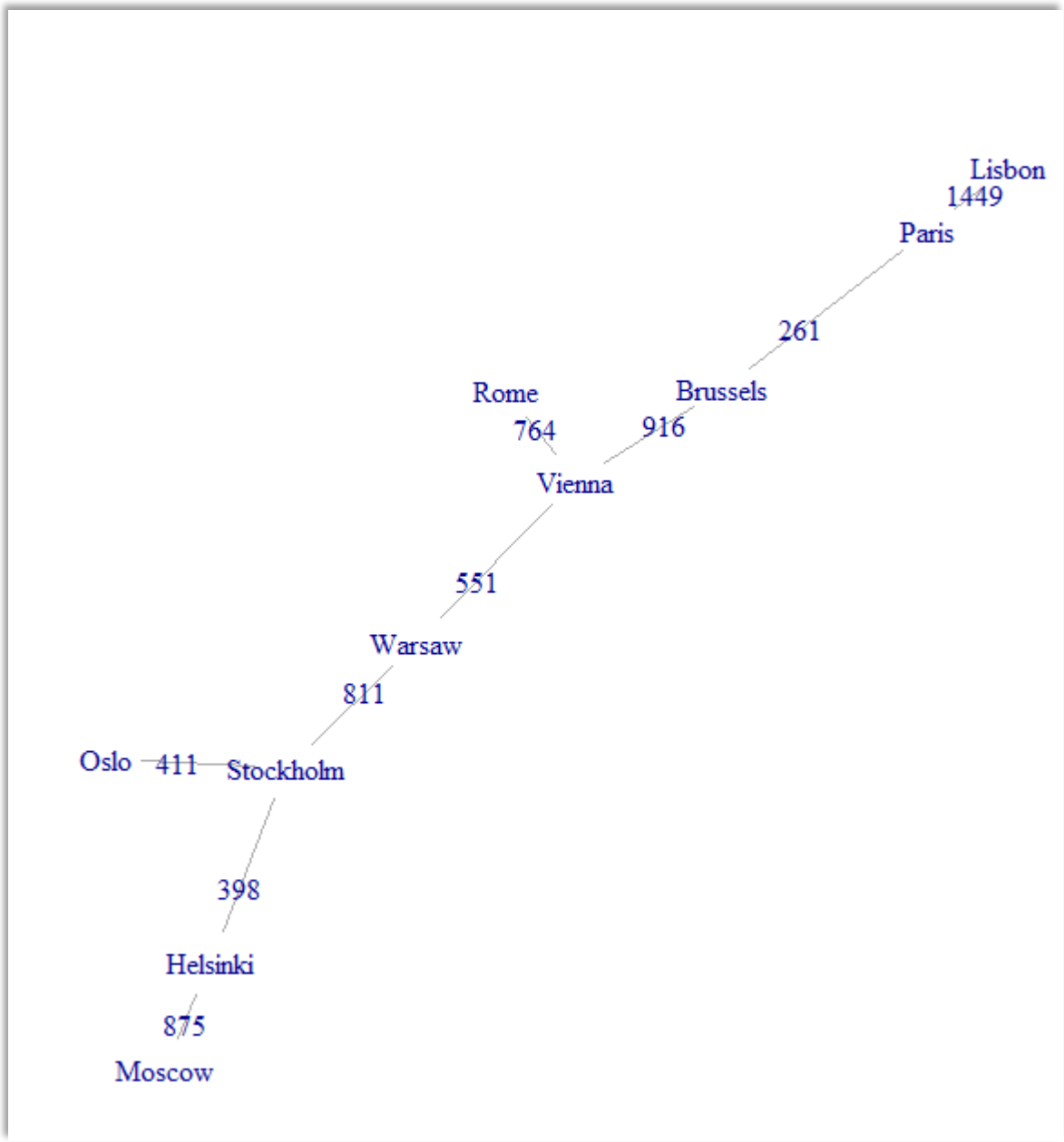

Figure 3.6(ii): Minimum Spanning Tree by Kruskal's Algorithm

Now to identify k = 3 clusters, maximum (k-1) edges are removed, shown in Figure 3.7

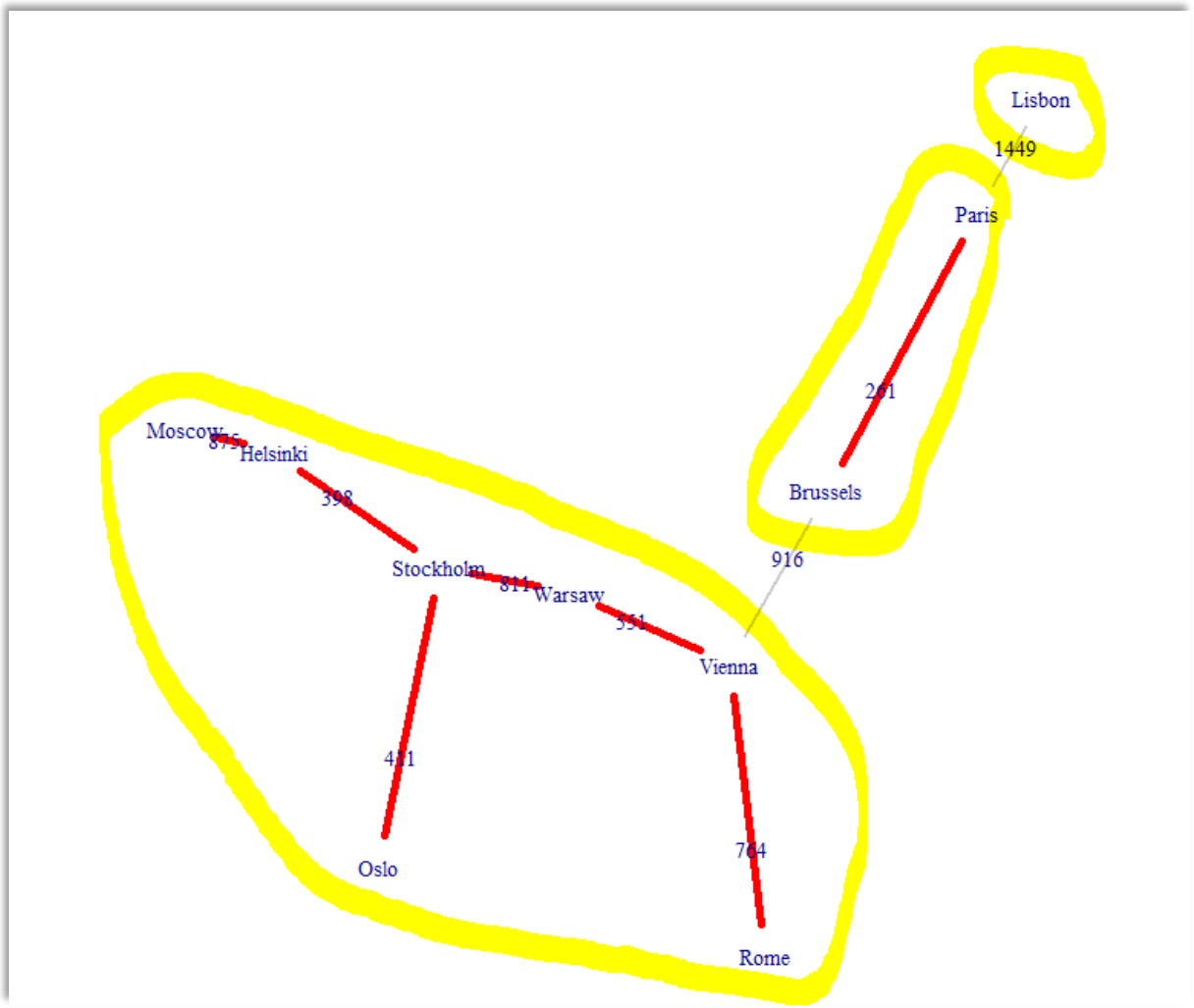

Figure 3.7: Three Clusters spanning the 10 Distribution Centres

3.2.2 LOCATION OF ADDITIONAL WAREHOUSES (Centre Of Gravity Method)

The three clusters, their comprising cities and details for the centres are detailed in this section. Also, their locations are shown on a map.

Cluster 1 – Comprises of Moscow, Warsaw, Helsinki, Oslo, Stockholm, Rome and Vienna.

Cluster 1 has a centre at "Jędrychówko, Poland" based on longitude 19.92393 and latitude 53.89658 calculated in R and shown in Figure 3.8

```
$ClusterNumber
[1] 1

$ClusterCities
[1] "Moscow"    "Warsaw"    "Helsinki"  "Oslo"      "Stockholm" "Rome"      "Vienna"

$GeoLocation
longitude.COGx  latitude.COGy
      19.92393       53.89658

$Centroid
[1] "Jędrychówko, Poland"
```

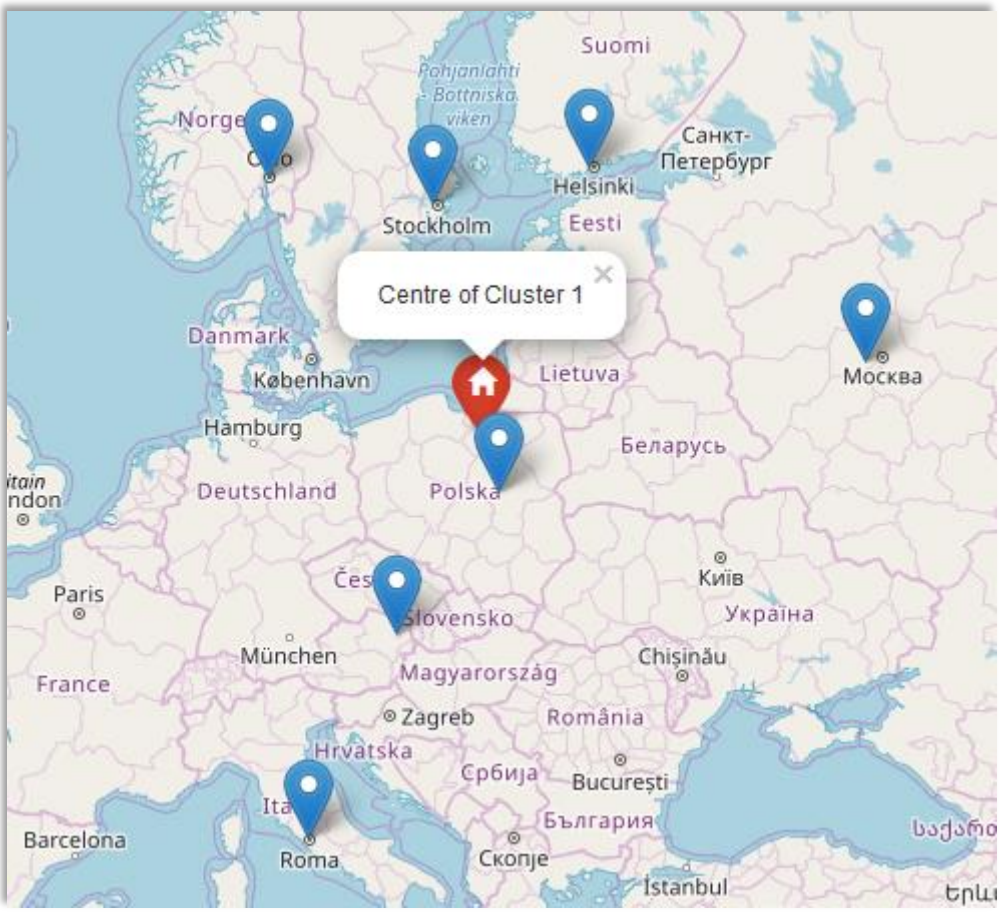

Figure 3.8: Cluster 1 and its Centre

Cluster 2 – Cluster 2 has a centre at “Lisbon, Portugal”, as it is the only Distribution Centre in this cluster.

The longitude -9.160203 and latitude 38.743627 calculated in R and shown in Figure 3.9

```
$ClusterNumber
[1] 2

$ClusterCities
[1] "Lisbon"

$GeoLocation
longitude.COGx  latitude.COGy
     -9.160203      38.743627

$Centroid
[1] "Lisbon, Portugal"
```

Figure 3.9: Cluster 2 and its Centre (single node)

Cluster 3 – Cluster 3 comprises of Brussels and Paris.

This has a centre at “Saint-Quentin, France”, with longitude 3.25017 and latitude 49.84889 calculated in R and shown in Figure 3.10

```
$ClusterNumber
[1] 3

$ClusterCities
[1] "Brussels" "Paris"

$GeoLocation
longitude.COGx  latitude.COGy
       3.25017       49.84889

$Centroid
[1] "Saint-Quentin, France"
```

Figure 3.10: Cluster 3 and its Centre

The longitude and latitude have been transformed to location using http://photon.komoot.de

3.2.3 DEMAND OF DISTRIBUTION CENTRES

From Demand information in section 3.1.1, the population sizes are listed in Table 3.5 followed by the calculated portion and actual demand in each distribution centre.

City	population	%of Total Population	tons/month
Lisbon	505,526	2.01%	6.85
Moscow	12,506,468	0	169.38
Warsaw	1,748,916	6.97%	23.69
Helsinki	631,695	0	8.56
Brussels	1,211,035	4.82%	16.40
Paris	2,140,526	0	28.99
Oslo	673,469	2.68%	9.12
Stockholm	962,154	0	13.03
Rome	2,857,321	11.38%	38.70
Vienna	1,868,000	0	25.30
Total	**25,105,110**	**100**	**340**

Table 3.8: Demand at Distribution Centres

Details from Table 3.8 and the analysis in the previous section are used and tabulated results showing the cities in their respective clusters along with the total demand is presented in Table 3.9

Also, the net capacity of the warehouses is shown which could assist in the planning of their sizes, all shown in Results part of this section.

3.3 RESULTS

The overall distance to be travelled (calculated by MST) is **6436 km**

The cost of transportation as calculated is **€ 13038**

Locations in Clusters and cities of Warehouses locations along with the capacities of each are shown below:

Distribution Centers	Demand Quantity (tons/month)
Cluster 1 - Warehouse	Jędrychówko, Poland
Moscow	169.38
Warsaw	23.69
Helsinki	8.56
Oslo	9.12
Stockholm	13.03
Rome	38.70
Vienna	25.30

Demand of Cluster 1	**287.76**
Cluster 2 - Warehouse	Lisbon, Portugal
Lisbon	6.85
Demand of Cluster 2	**6.85**
Cluster 3 - Warehouse	Saint-Quentin, France
Brussels	16.40
Paris	28.99
Demand of Cluster 3	**45.39**
Total Demand	**340**

Table 3.9: Clusters and their Demands

RESOURCES AND REFERENCES

1. Garn, W. (2018). Introduction to Management Science. 1st ed. London: CreateSpace Independent Publishing Platform (21 Dec. 2018).
2. Website like Indeed.com for salary calculation and Zoopla for factory and warehouse for purchase.
3. Factory and equipment for the financial statements and quotation provided by suppliers. file:///Users/nehakashyap/Desktop/60-100kgh automatic banana chips line.pdf
4. Actual processing of the product - links of processing steps - https://www.potatochipsmachinery.com/potato-chips-making-line/semi-automatic-banana-chips-plant.html
5. Financial statement of a company - https://www.sausd.us/cms/lib/CA01000471/Centricity/Domain/494/TOTWFinancial.pdf
6. Freight Rate Calculator https://www.worldfreightrates.com/en/freight
7. Supplier Information - https://www.alibaba.com/
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9. Distance calculations - https://www.searates.com/reference/portdistance/
10. To find the location details based of geometric coordinate - http://photon.komoot.de