Supply chain network design

Use the (.dat/.csv) files provided to you, to solve the following mathematical optimization problems according to the question instructions.

The marks distribution for the tasks: 30, 40, 30 for the three questions respectively.

The .dat files are intended for the AMPL users, and the .csv files are intended for the Python users. The models would be best solved using the GUROBI solver.

For submission, you have to upload the following combined into a .ZIP file:
1) .mod files or python file containing the model which will be run on the original data.
2) the written mathematical model used for the implementation of each question, together in the form of a PDF. Also include the results in this file.
3) the contents of the same .mod file copied into a text editor and saved as PDF (to be used if the .mod file you uploaded cannot be opened for some reason).

1. The company XYZ has decided to produce bioethanol in the state of Texas. The company needs to design a supply chain consisting of suppliers and biorefineries for the conversion of raw material (i.e., biomass) into biofuel. The **suppliers** of biomass are represented by the **counties** in the state of Texas; it is assumed that the centroid of the county is the county seat. A total of 254 counties are available to supply the necessary feedstock for the production process. The supply information is provided in the file **"suppliers(.csv/.dat)"**. The amount of supply at each county is given in Mg (Mega gram = 1 million gram, also called tonne).

   The potential locations to open the **biorefineries (plants)** are obtained from feasibility studies conducted by government agencies. There are 167 such potential refinery locations and data about them are in the file **"plants(.csv/.dat)"**. The investment cost to maintain a biorefinery, and the yield in litres of **bioethanol** per Mg of biomass, are presented in Table 1. In total, the company aims to produce **500,000,000 liters** of bioethanol for the project to achieve the required financial gains from this project.

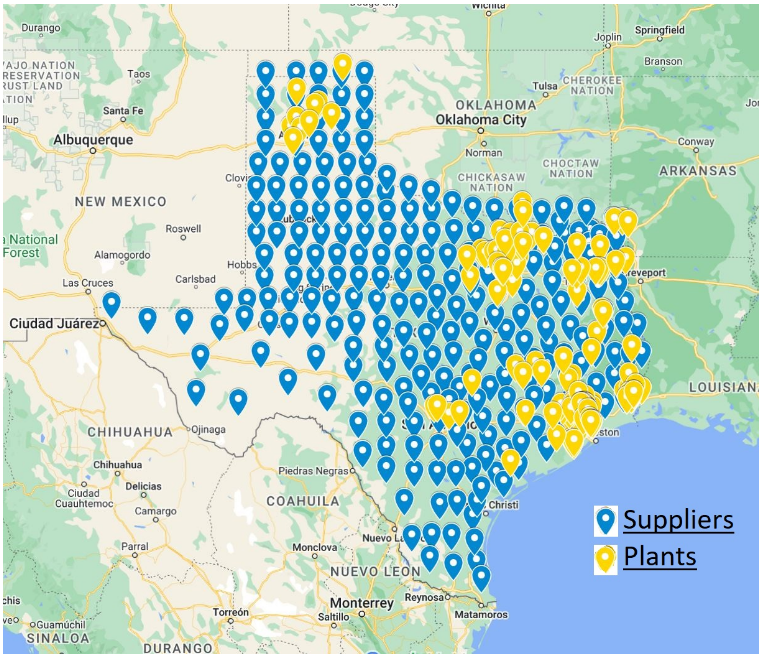

Figure 1: The actual locations of the suppliers (counties) and potential refineries (plants) shown on the map.

   The company uses its trucks for the transportation of biomass from the counties to the refineries along roads. The distances (km) and transportation costs ($/Mg per km) for each supplier-hub path are presented in the

Parameter	Value
Investment cost (Equivalent Annualized Cost)	$ 130,956,797
Annual conversion capacity	152,063,705 liters of bioethanol
Conversion yield of bioethanol	232 liters per Mg of biomass

Table 1: Biorefinery parameters

file "roads_s_p(.csv/.dat)". Each time the truck is loaded or unloaded, a cost of $5,000 is incurred, so in total for each trip of the truck, a cost of $10,000 is incurred. This is assumed to be independent of the total load of the truck because the demands are much more than the capacity of the truck, which is 500 Mg. Therefore, to deliver the quantities from one county to one plant, many trips of the truck might be required.

Transportation	Mode	Combined cost of loading and unloading per vehicle	Capacity of truck
Counties to plants	By road on trucks ("roads_s_p(.csv/.dat)")	$ 10,000	500 Mg of biomass

Table 2: Transportation details for the supplier-plant network

Formulate and solve a mathematical model to find the locations for building the refineries and the way of supplying the biomass from the counties to the built refineries, in such a way that the total cost involved is minimized.

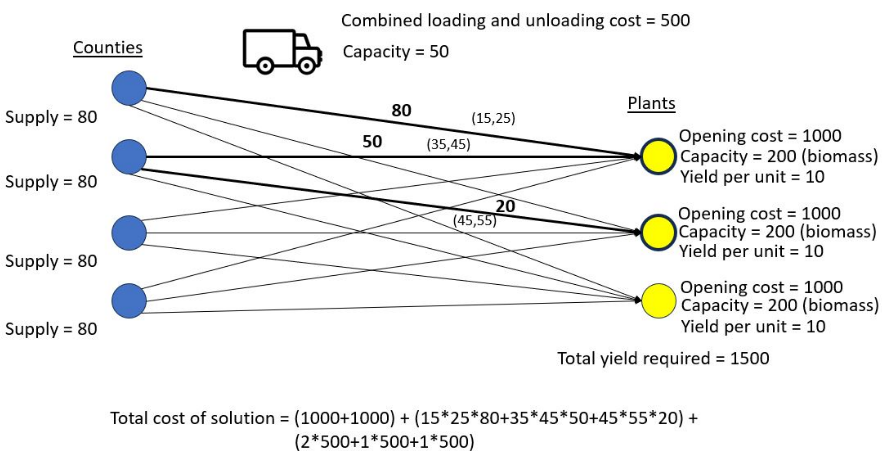

Figure 2: Toy example for cost calculation of a solution of question 1. The chosen plants and edges are highlighted in bold and the flow along these edges is also shown. Along each edge is given the corresponding cost per Mg per km and distance in km, respectively. For simplicity, these values are not shown for the other edges.

2. The company decides to explore the potential of building intermediate hubs to consolidate the biomass from the suppliers to reduce the transportation cost. The potential locations to open hubs correspond to train stations (see the file **"hubs(.csv/.dat)"**) because the transportation mode utilized to move the raw material from the hubs to the biorefineries is by train. Also, direct transportation of biomass from the suppliers to the refineries is not allowed anymore. Instead, now the supply from the suppliers has to first be transported to the hubs by road on trucks (the data for which is given in the file ("roads_s_h(.csv/.dat)")) and then from the hubs to plants by train. As before, in this case, multiple train trips might be required to deliver everything from one hub to one plant.

   The distances (km) and transportation costs ($/Mg per km) for each hub-plant path are included in the file "railroads_h_p(.csv/.dat)". The cost of loading or unloading a train is $ 30,000 (again, irrespective of the load of the train), so in total for each train trip, a cost of $60,000 is incurred and the train capacity is 20,000 Mg. The hubs serve only as transshipment nodes, no storage of material is allowed. The cost of maintaining a hub and its capacity are given in Table 3.

   Ignore all the results from the solution of question 1 and instead formulate and solve a mathematical model to redesign the supply chain according to the new scheme, and find the new set of plants and hubs to build and the supply from the suppliers to the built hubs and from these hubs to the built plants, in such a way that the total cost is minimized.

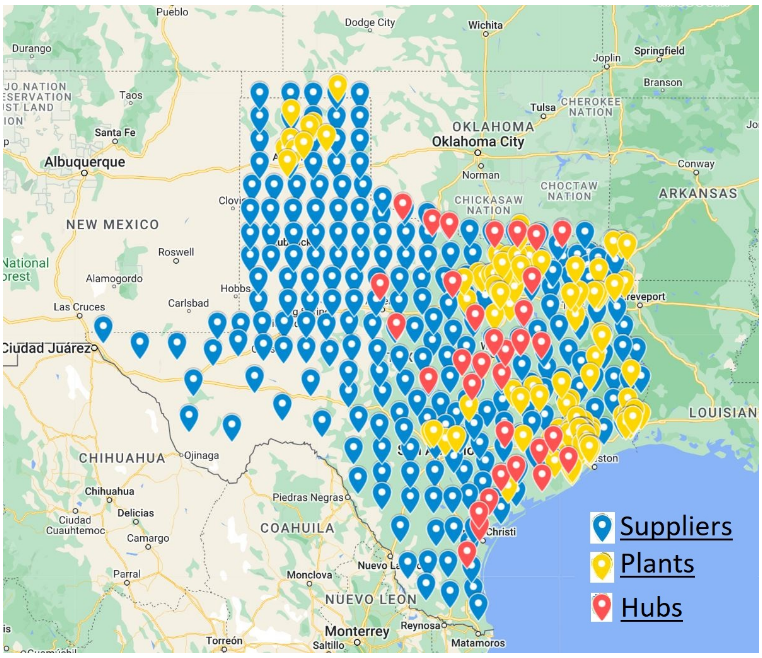

Figure 3: The actual locations of the suppliers (counties), potential hubs and refineries (plants) shown on map.

Parameter	**Value**
Investment cost (Equivalent Annualized Cost)	$ 3,476,219
Annual processing capacity	300,000 Mg of biomass

Table 3: Hub parameters

Transportation	**Mode**	**Combined cost of loading and unloading per vehicle**	**Capacity of truck**
Counties to hubs	By road on trucks ("roads_s_h(.csv/.dat)")	$ 10,000	500 Mg of biomass
Hubs to plants	By trains ("railroads_h_p(.csv/.dat)")	$ 60,000	20,000 Mg of biomass

Table 4: Transportation details for the supplier-hub-plant network

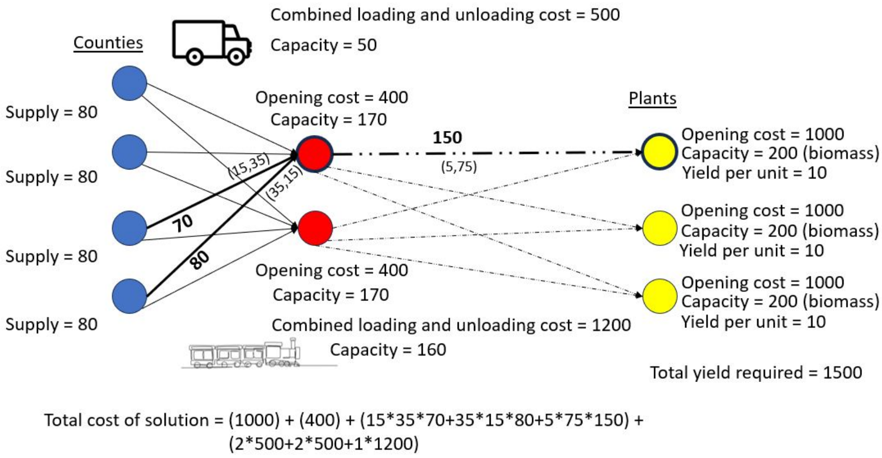

Figure 4: Toy example for cost calculation of a solution of question 2. The chosen plants and hubs and edges are highlighted in bold and the flow along these edges is also shown. Along each edge is given the corresponding cost per Mg per km and distance in km, respectively. For simplicity, these values are not shown for the other edges.

3. Until now, we have considered only the cases when the bioethanol demand for the state was possible to be met by the available suppliers. Now, assume that the company wants to produce **800,000,000 liters** of bioethanol. Then the total demand cannot be met by the suppliers and therefore a third party supply must also be used,

and **the biomass bought from the third party needs to be sent through the hubs**. The third-party price can be assumed as **$2,000 Per Mg**, without regards to the transportation costs required for the third-party provider as their location is unknown. Include the third-party supply (at unknown location/s) along with the available supply from the suppliers and redesign the supply chain with a new set of hubs and plants to be built and the new supply of biomass to the hubs.

Again, ignore all the previous results and mathematically formulate the problem and solve it to minimize the total cost of this project. The input to be used for this task is the same as in question 2, the only difference is that the demand for bioethanol is much more now and an unlimited third-party supply can be also included in the network along with the other suppliers.

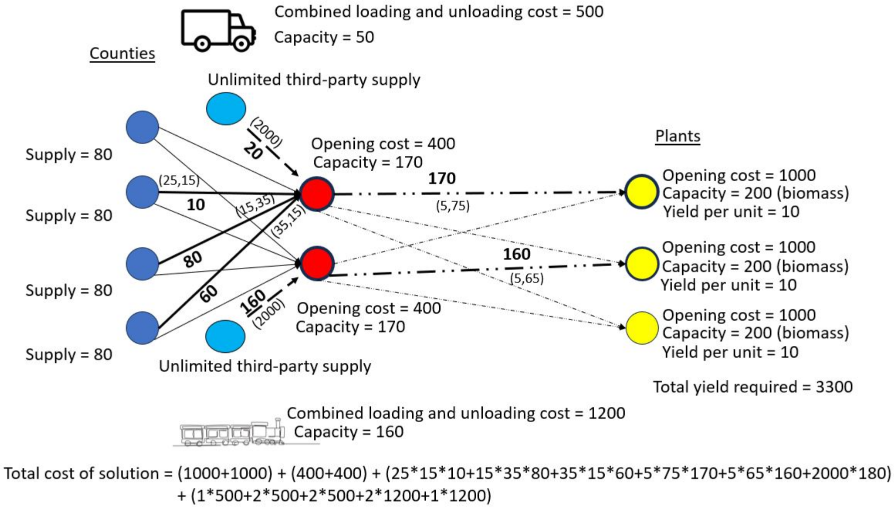

Figure 5: Toy example for cost calculation of a solution of question 3. The chosen plants and hubs and edges are highlighted in bold and the flow along these edges is also shown. The amount of third-party supply to the chosen hubs is also shown, the cost of which does not depend on any distance. Along each edge is given the corresponding cost per Mg per km and distance in km. For simplicity, these values are not shown for the other edges. For the edges representing third-party supply into the hubs, the cost per Mg is also shown.

NB: In all of the three situations in the questions, fractional flows of the biomass is allowed, because the unit of biomass here is very big (1 Mg = 1 million grams).