ISE 4623/5023: Deterministic Systems Models / Systems Optimization University of Oklahoma School of Industrial and Systems Engineering Fall 2024

Instructions for Assignment Submission:

1. The assignment must be uploaded to Canvas by the indicated due date. The solution should be uploaded to Canvas as a PDF file.
2. Along with your main submission (in PDF format), please ensure you also attach any supplementary files (Excel, Python) that were instrumental in your work. If any Python code was used, upload it in HTML format.
3. If you've used Python or Excel, **kindly incorporate all relevant screenshots into your primary submission**. Phrases like *See Excel sheet* or *solved in Python* won't be accepted. While you're encouraged to use these tools, your primary submission (the PDF) should be comprehensive enough for grading.
4. Always label your answers with the corresponding problem number for clarity.

Individual Assignment 6: Transportation and MCFP

1. (50 points) Sooners Inc., a company known for producing, packaging, and distributing high-quality Oklahoma-style barbecue sauces, works with three suppliers of raw ingredients located across the U.S. These ingredients are essential for producing their sauces. The company operates three production plants that receive these ingredients. Each supplier can ship a certain amount of raw ingredients (measured in tons) per week, and each production plant has known weekly ingredient requirements. Shipping costs from each supplier to each production plant are also known. Table 1 shows the transportation cost from each supplier to each production plant, the total ingredient availability at each supplier, and the total ingredient requirement at each production plant.

Table 1: Transportation costs, per ton, from suppliers to production plants

From/To	Plant 1	Plant 2	Plant 3	Supplier availability (tons)
Supplier 1	\$320	\$215	\$400	50
Supplier 2	\$410	\$245	\$360	120
Supplier 3	\$290	\$460	\$190	180
Plant requirements (tons)	80	90	60	

   (a) (15 points) Using the provided information, determine how many tons of raw ingredients each supplier should ship to each production plant to meet the demand at each location with minimum cost. Formulate the optimization model based on the structure of the "Transportation Problem." Clearly define sets, parameters, decision variables, objective functions, and constraints.

   (b) (15 points) What is the optimal transportation strategy (the quantity of raw ingredients shipped from each supplier to each production plant) that minimizes total cost? Solve the problem using Excel or Gurobi, showing your results clearly. Discuss your findings.

   (c) (10 points) Reformulate the problem under the assumption that each supplier loses 40%, 60%, and 25% of their raw ingredient availability due to unforeseen disruptions. Solve the problem using Excel or Gurobi and provide a detailed comparison with the results from part b. How do the transportation strategies differ between the two scenarios?

   (d) (10 points) In the context previous to the disruptions (before part c), Sooners Inc. has decided to experiment by allowing one of the production plants to ship raw ingredients to another plant to reduce overall costs. For simplicity, that plant is allowed to ship to exactly one other plant, while the other plants cannot send any ingredients. Table 2 shows the costs (per ton) of shipping raw materials from one plant to another. Model this new scenario, taking the internal shipping option into account, and formulate the optimization problem. Provide the optimal transportation strategy, solving the model using Excel or Gurobi.

Table 2: Transportation costs, per ton, between production plants

From/To	Plant 1	Plant 2	Plant 3
Plant 1	-	$15	$20
Plant 2	$30	-	$25
Plant 3	$20	$15	-

2. (45 points) Efficient transportation is pivotal in ensuring a cost-effective supply chain and affordable products for customers. Sooners Inc., renowned for its high-quality Oklahoma-style barbecue sauces, has recently expanded to Austin, Texas, leveraging three strategically located hubs in Norman, Oklahoma. Their primary objective is to optimize the supply chain by minimizing transportation costs and addressing weekly unmet demand while fulfilling orders from five major Austin-based customers. The process involves production and packing at the Norman hubs, followed by distribution to Austin warehouses, and ultimately delivery to end customers. The challenge now includes producing and delivering two types of barbecue sauces: the regular sauce and the new Extra Spicy Oklahoma Blaze, which have separate processing and distribution requirements.

   Tables 3 and 4 provide crucial transportation cost data for both types of sauces, and Table 5 shows the weekly demand for both regular and special sauces from each customer.

Table 3: Transportation costs, per order, from hubs to warehouses (same for both sauces)

From/To	Warehouse 1	Warehouse 2	Warehouse 3
Hub 1	$100	$370	$90
Hub 2	$225	$450	$300
Hub 3	$150	$400	$200

Table 4: Transportation costs, per order, from warehouses to customers for both sauces

From/To	Customer 1	Customer 2	Customer 3	Customer 4	Customer 5
Warehouse 1	$50	$70	$30	$25	$50
Warehouse 2	$60	$40	$75	$40	$75
Warehouse 3	$50	$35	$30	$80	$50

Table 5: Weekly orders made by the customers for regular and special sauces

Customer	Regular sauce demand	Special sauce demand
Customer 1	200	100
Customer 2	250	50
Customer 3	150	100
Customer 4	100	200
Customer 5	200	350

The cost of unmet demand per order at each customer is provided in Table 6, which varies by customer and sauce type.

Table 6: Cost of unmet demand per order at each customer

Customer	1	2	3	4	5
Cost per unit (regular sauce)	$850	$600	$950	$150	$50
Cost per unit (special sauce)	$250	$600	$50	$650	$1000

There are also limitations on the number of orders that can be sent from hubs to warehouses and from warehouses to customers. This means that only a certain number of orders can be sent through each origin-destination pair. Tables 7 and 8 show the maximum allowable order flows.

Table 7: Maximum weekly number of orders that can be sent from each hub to each warehouse (for both sauces combined)

From/To	Warehouse 1	Warehouse 2	Warehouse 3
Hub 1	50	30	60
Hub 2	40	35	85
Hub 3	45	50	55

Table 8: Maximum weekly number of orders that can be sent from each warehouse to each customer (for both sauces combined)

From/To	Customer 1	Customer 2	Customer 3	Customer 4	Customer 5
Warehouse 1	40	35	25	50	25
Warehouse 2	45	35	25	10	60
Warehouse 3	65	30	40	20	50

(a) (25 points) Formulate the necessary objective function and constraints to minimize the combined transportation and unmet demand costs for both the regular and special sauces. Clearly define the decision variables, objective function, and constraints.

(b) (25 points) What is the transportation strategy (amount of orders shipped from each hub to each warehouse, and from each warehouse to each customer) that minimizes the total cost for both sauces? Additionally, report the total unmet demand for both sauces. Solve the problem using Excel or Gurobi, show your results clearly, and discuss.