

## IE 202 Assignment

**Due: December 31<sup>st</sup> 2021, 17.00**

XYZ is a glass bottle manufacturer which has four plants (P1, P2, P3, and P4) and five customers at cities 1, 2, 3, 4 and 5. The production capacities at plants are given in Table 1. Based on past data, average demand at each city for the following months is estimated as in Table 2. Currently, the products are shipped from the plants to the customer locations by train. Due to increasing shipping costs, the company is considering using ships and this alternative will require some investment. The shipping costs (per 1000 units) are given in Table 3 for the current shipping strategy (by rail) and for the new one (excluding the investment costs).

**Table 1**

Plant	Monthly Production Capacity (1000 bottles)
1	290
2	220
3	180
4	280

**Table 2**

Customer	Monthly Demand (1000 bottles)
1	180
2	200
3	160
4	140
5	250

**Table 3**

	Unit Cost by Rail (\$1000)					Unit Cost by Ship (\$1000)				
	Customer					Customer				
Plant	1	2	3	4	5	1	2	3	4	5
1	8.5	7	8	6.5	9	5.5	6	--	3.5	4
2	7.5	8	7	10	8.5	3	4.5	4	6.5	6
3	11	6	6.5	8	7	--	--	3	4	4.5
4	9	7	12	6	7.5	5	4.5	7	3	--

It is assumed that if invested, a ship will be on service for 10 years and once a shipping plan is obtained, it will not change in the lifetime of the ships. The ship type invested depends on the amount transported. Hence the investment cost is assumed to be proportional to the shipment amount on that route. The required investment on ships for one thousand units to be transported by ship is given as in the following table, for each route. After some economics analysis (taking the time value of the money into consideration) it is decided that monthly equivalent cost of an investment will be one-twentieth of it.

**Table 4**

	<b>Investment Cost for Ships (\$1000)</b>				
	Customer				
<b>Plant</b>	1	2	3	4	5
<b>1</b>	40	60	--	40	80
<b>2</b>	60	40	80	20	40
<b>3</b>	--	--	80	60	100
<b>4</b>	100	60	60	80	--

1. (30 pts) What is the optimal shipping strategy for each of the following cases? What is the total cost for each of them?
  - a. If the company does not want to invest in ships.
  - b. If ships are used only (except the routes that transportation by ships is not feasible. For such routes, you can do transportation by rail.)
  - c. If the shipping choice on each route are independent.

Formulate and solve the problems on GAMS. Submit your GAMS model (.gms file). Define the decision variables explicitly. In the report, provide shipment amounts and the objective values for each part.

2. (40 pts) Assume that you decided to use the plan with the minimum cost in question 1. Answer the following questions accordingly and treat each case independently.
  - a. The production team realized that they made a mistake in the estimation of second plant's capacity. The true capacity is 230 instead of 220. Estimate the new total cost without solving an LP. Then, check your result by resolving the problem.
  - b. The sales team realized that they made a mistake in the estimation of second customer's demand. The true estimate is 195 instead of 200. Estimate the new total cost without solving an LP.
  - c. Assume that the true capacity of the second plant is 400 instead of 220. Guess the new total cost without solving an LP. Now, solve the new LP and comment why it is not possible to calculate the total cost without resolving the problem.
  - d. What is the range of unit cost at route 1-4 (Plant 1 – Customer 4) that the optimal plan does not change?
  - e. The top management asks you to change the plan such that there must be some flow on route 3-1. What is the minimum decrease in the shipping cost on 3-1 route that will yield a new plan as the top management wants?

Clearly explain your reasoning for each part. Use economic interpretation of LP. (No code files for this question.)

3. (30 pts) Consider the case in Question 1-b. The investment cost of ships is assumed to be proportional to the flow in that part. Now, we decide to rent ships for one month. The monthly rent is \$350,000 independent of the flow on that route.
- a. Formulate a MIP and find the optimal shipment plan on GAMS.
  - b. There are some restrictions on renting. If we rent a ship on route 3-3, then we cannot rent on route 1-4; and the maximum number of ships rented cannot exceed 4. What is the new total cost

Formulate and solve the problems using GAMS. Submit your GAMS model (.gms file). Define the decision variables and the additional constraints in the report explicitly. Provide shipment amounts and the objective values for each part.

**Note that this is an individual work assignment. You are expected to formulate the problem and solve by GAMS. The main body of the report should include your formulation (with the definition of parameters and decision variables) and answers to Questions 1-3 together with discussions and comments. In the report, provide the answers for each part. Also, do not forget to submit your GAMS files, which should include comments if necessary.**