**Answers**

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**Question 1**

**Option 1**

In this option, we opened the new refinery in Los Angeles. Then we solve the problem with GAMS.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | New Orleans | Charleston | Seattle | Los Angeles | Supply |
| Texas | 40 | 0 | 0 | 40 | 80 |
| California | 0 | 0 | 0 | 60 | 60 |
| Alaska | 0 | 0 | 80 | 20 | 100 |
| Middle East | 60 | 60 | 0 | 0 | 120 |
| Demand | 100 | 60 | 80 | 120 |  |

Table 1: Optimal # of barrels sent from oil field i to refinery j (in millions)

z\*=$1,500,000

**Option 2**

In this option, we opened the new refinery in Galveston. Then we solve the problem with GAMS.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | New Orleans | Charleston | Seattle | Galveston | Supply |
| Texas | 0 | 0 | 0 | 80 | 80 |
| California | 0 | 20 | 0 | 40 | 60 |
| Alaska | 20 | 0 | 80 | 0 | 100 |
| Middle East | 80 | 40 | 0 | 0 | 120 |
| Demand | 100 | 60 | 80 | 120 |  |

Table 2: Optimal # of barrels sent from oil field i to refinery j (in millions)

z\* = $1,490,000

**Option 3**

In this option, we opened the new refinery in Galveston. Then we solve the problem with GAMS.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | New Orleans | Charleston | 2 | St. Louis | Supply |
| Texas | 0 | 0 | 0 | 80 | 80 |
| California | 0 | 20 | 0 | 40 | 60 |
| Alaska | 20 | 0 | 80 | 0 | 100 |
| Middle East | 80 | 40 | 0 | 0 | 120 |
| Demand | 100 | 60 | 80 | 120 |  |

Table 3: Optimal # of barrels sent from oil field i to refinery j (in millions)

z\* = $1,500,000

**Conclusion:** We determined that option two has the minimum z\* value ($1,490,000). So, we chose Galveston for opening the new refinery. In the following questions, we used option 2.

**Question 2**

For this question, we added 2 more constraints which are x23=60, x33=20 and solved in GAMS. The objective value increased from $1,490,000 to $1,590,000. This means the shipment isn’t improved. The solution turned to this:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | New Orleans | Charleston | Seattle | Galveston | Supply |
| Texas | 0 | 0 | 0 | 80 | 80 |
| California | 0 | 0 | 60 | 0 | 60 |
| Alaska | 40 | 0 | 20 | 40 | 100 |
| Middle East | 60 | 60 | 0 | 0 | 120 |
| Demand | 100 | 60 | 80 | 120 |  |

Before solving this problem, our reduced costs were x23=1,000, x33=0. Since we put x23 to ourbasis this reduced cost needs to be multiplied by # of units we sent from oil fields to the refineries. Then we need to add this cost to our optimal z value.

Our z\* is $1,590,000.

**Question 3**

If we look at our current optimal solution we can say that x23 is not in the basis. So, if we want to have a relationship between oil field 2 - refinery 3 we must pay $ 1,000 per million barrels of x23 in addition. We call these additional costs reduced cost. We can see the reduced costs for each decision variable from GAMS.

**Question 4**

In a possible change of the crude oil, the total cost can be affected by two ways:

**1. A decrease of crude oil**

If crude oil decreases, our new model will be unbalanced, and we will not able to satisfy the demand, so our solution will be infeasible. In conclusion, any decrease in supply causes infeasibility according to excess demand.

**2. An increase of crude oil**

If crude oil increases, there will be excess of supplies. Increasing the supply does not have any effect on the feasibility of the model because excess supplies stored in dummy plants which gams automatically generates so the demand is satisfied. The company can store the excess crude oil at their warehouses.

\* If we increase the supply 1 we would decrease our cost by $3,000

\* If we increase the supply 2 we would decrease our cost by $1,000

\* If we increase the supply 3 we would not decrease our cost because other suppliers are preferable, so any extra supply does not cause any change in our cost.

\* If we increase the supply 4 we would decrease our cost by $3,000