Network Planning

**Model formulation:**

Consider the following distribution system:

* Single product.
* Two plants, referred to as plant p1 and plant p2.
* Plant p2 has an annual capacity of 60,000 units.
* The two plants have the same production costs.
* Two existing warehouses, referred to as warehouse w1 and warehouse w2, have identical warehouse handling costs.
* Four markets' areas, c1, c2, c3, c4 with demands of 50,000, 100,000, 50,000, and 20000 respectively. And the demand of c4 can only be served from warehouse 1

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Warhouse | P1 | P2 | C1 | C2 | C3 | C4 |
| W1 | 0 | 4 | 3 | 4 | 5 | 4 |
| W2 | 5 | 2 | 2 | 1 | 2 | 0 |

* A service level constraint here: For market areas c1, c2, c3, c4 we allow one of them to be not fully served, in other words one of their demands can be satisfied down to the 80% level.

optimization problem is the following:

Objective

� �Mi𝑛 0𝑥(𝑝1,𝑤1) +5𝑥(𝑝1,𝑤2) +4𝑥(𝑝2,𝑤1)+2𝑥(𝑝2,𝑤2) +3𝑥(𝑤1,𝑐1) +4𝑥(𝑤1,𝑐2) + 5𝑥(𝑤1,𝑐3) +4𝑥(𝑤1,𝑐4) +2𝑥(𝑤2,𝑐1) +1𝑥(𝑤2,𝑐2) +2𝑥(𝑤2,𝑐3)

subject to

� �(𝑝2,𝑤1) + 𝑥(𝑝2,𝑤2) ≤ 60,000 � �

(𝑝1,𝑤1) + 𝑥(𝑝2,𝑤1) = 𝑥(𝑤1,𝑐1) +𝑥(𝑤1,𝑐2) +𝑥(𝑤1,𝑐3) +𝑥(𝑤1,𝑐4) � �

(𝑝1,𝑤2) + 𝑥(𝑝2,𝑤2) = 𝑥(𝑤2,𝑐1) +𝑥(𝑤2,𝑐2)+𝑥(𝑤2,𝑐3) � �

(𝑤1,𝑐1) + 𝑥(𝑤2,𝑐1) = 𝑑1, 𝑑1 = 50,000−𝑦1 ×10,000 � �

(𝑤1,𝑐2) + 𝑥(𝑤2,𝑐2) = 𝑑2, 𝑑2 = 100,000−𝑦2 ×20,000 �

�(𝑤1,𝑐3) + 𝑥(𝑤2,𝑐3) = 𝑑3,𝑑3 = 50,000−𝑦3 ×10,000 �

�(𝑤1,𝑐4) = 𝑑4,𝑑4 = 20,000−𝑦4 ×4,000 �

�1 +𝑦2 +𝑦3 +𝑦4 =1 AND (2) �

�(𝑝1,𝑤1),𝑥(𝑝1,𝑤2),𝑥(𝑝2,𝑤1),𝑥(𝑝2,𝑤2) ≥ 0 �

�(𝑤1,𝑐1),𝑥(𝑤1,𝑐2),𝑥(𝑤1,𝑐3),𝑥(𝑤1,𝑐4) ≥ 0 � �

(𝑤2,𝑐1),𝑥(𝑤2,𝑐2),𝑥(𝑤2,𝑐3) ≥ 0 �

�1, 𝑦2, 𝑦3,𝑦4 ∈ {0,1}

The optimal solution

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Warhouse | P1 | P2 | C1 | C2 | C3 | C4 |
| W1 | 140000 | 0 | 50000 | 70000 | 0 | 20000 |
| W2 | 0 | 60000 | 0 | 10000 | 50000 | 0 |

**Explainability:** A user may ask the following questions:

1. What would happen if the demand at market c1 increased by 10%?
2. What would happen if the demands at all market’s demond doubled?
3. Why are we using warehouse w1 for plant p1?
4. Can I use warehouse w1 only for market c3?
5. What if plant p2 can now supply only half of its original capacity?
6. The per-unit distribution cost from plant p2 to warehouse w1 is now $5. How does that affect the total cost?
7. Why does plant p1 produce more products for market c2 than for market c1?
8. Why does warehouse w2 receive more shipments from plant p2 than warehouse w1?
9. Why not only use one warehouse for all markets?