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(3-a)

i) Decision Variables.

X_1: 1 product manufactured at the plant 1, $X_1 \in \mathbb{Z}$

X_2: 2 product manufactured at the plant 2, $X_2 \in \mathbb{Z}$

X_3: 3 product manufactured at the plant 3, $X_3 \in \mathbb{Z}$

X_4: 4 product manufactured at the plant 4, $X_4 \in \mathbb{Z}$

M: Big M, 80000

y_1: running the plant 1 Line or not, $y_1 \in \{0,1\}$

y_2: running the plant 2 Line or not, $y_2 \in \{0,1\}$

y_3: running the plant 3 Line or not, $y_3 \in \{0,1\}$

y_4: running the plant 4 Line or not, $y_4 \in \{0,1\}$

V: Auxiliary variable, $V \in \{0,1\}$

ii) Objective function.

Maximise profit: $70X_1 + 60X_2 + 90X_3 + 80X_4$
$\quad - 50000y_1 - 40000y_2 - 70000y_3 - 60000y_4$

iii) Constraints.

- Demand limit for each product
  - $X_1 \leq 10000$, $X_2 \leq 15000$, $X_3 \leq 12500$, $X_4 \leq 9000$
- At most two lines should be produced
  - $y_1 + y_2 + y_3 + y_4 \leq 2$
- If either line 1 or line 2 is running, the line 3 can only run
  - $y_1 + y_2 \geq y_3 \rightarrow y_1 + y_2 - y_3 \geq 0$
- Either Line1 + line2 are below 20,000 or line3 + line4 are below 20,000
  - $X_1 + X_2 \leq 20000 + M \cdot V$, where $M = 80000$ (Big M), $V \in \{0,1\}$
  - $X_3 + X_4 \leq 20000 + M \cdot (1 - V)$, where $M = 80000$ (Big M), $V \in \{0,1\}$
- Line & product binding
  - $X_1 \leq My_1$, $X_2 \leq My_2$, $X_3 \leq My_3$, $X_4 \leq My_4$
- Non-negativeness
  - $X_1, X_2, X_3, X_4 \geq 0$

(4-a)

i) Decision variables

- c: the number of the furniture from Caroline
- n: 〃 from Nashawtuc
- a: 〃 from Adirondack
- l: 〃 from Lancaster.
  - $c, n, a, l \in \mathbb{Z}$

- cd: the delivery charge if accepting the bid from Caroline
- nd: 〃 from Nashawtuc
- ad: 〃 from Adirondack
- ld: 〃 from Lancaster.
  - $cd, nd, ad, ld \in \{0, 1\}$

ii) Objective function.

- Minimise cost: $2500c + 2450n + 2510a + 2470l + 10000cd + 20000nd + 0 \times ad + 13000ld$

iii) Constraints.

- Demand: $c + n + a + l \geq 2000$
- Linking capacity: $c \leq M \cdot cd$, $n \leq M \cdot nd$, $a \leq M ad$, $l \leq M \cdot ld$.
  Big M = 40000
- Supply capacity
  - $c \leq 1000$
  - $n \leq 1200$
  - $a \leq 800$
  - $l \leq 1100$
- Nonnegativity
  - $c, n, a, l \geq 0$

(4-b) The AMPL file is attached.

The optimal solution is Nashawtuc = 1200 & Lancaster = 800 with the optimal value of £4944000.

(4-c)

i) New Decision Variables added to the original one.

- d: the number of furniture from Delaware
- dr: 〃 from Delaware at reduce cost.

$d, dr \in \mathbb{Z}$

- dd: the delivery charge if accepting the bid from
- drd: 〃 〃 at reduce cost.

$dd, drd \in \{0,1\}$

ii) New Objective function.

- Minimise cost: $2500c + 2450n + 2570a + 2410l + 2530d + 2430dr + 10000cd + 20000nd + 0ad + 13000ld + 9000dd + 7000drd$.

iii) Constraints

- Demand: $c + n + a + l + d + dr \geq 2000$
- Linking Capacity: $c \leq M \cdot cd$, $n \leq M \cdot nd$, $a \leq M \cdot ad$, $l \leq M \cdot ld$, $d \leq M \cdot dd$, $dr \leq M \cdot drd$

  M = big $M = 100000$.
- Supply Capacity
  - $c \leq 1000$
  - $n \leq 1200$
  - $a \leq 800$
  - $l \leq 1100$
  - $d \leq 1000$
  - $dr \leq 500$
- $dd \geq drd$.
- $d \geq 1000 \cdot drd$. (reduced price is available after 1000 at an original price)

⇒ AMPL File is attached. The optimal solution and value are same as (4-a)