Assignment 2

Module 2 - The LP Model

Course: QUANTITATIVE MANAGEMENT MODELING (BA-64018-001), Fall 2023

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Name: Miri Chung

Kent State User ID: mchung8

Student ID: 811176241

Problem 1.

(a) Clearly define the decision variables.

Answer: Decision variables refer to the specific factors or quantities that decision-makers must determine. In the context of the 'Back Savers' scenario, the decision variables are the quantities of each backpack type, both Collegiate and Mini, that need to be produced weekly.

(b) What is the objective function?

Answer) The objective function is to maximize the total profit, represented by the equation,

$\$32 \times x1 + \$24 \times x2$,

where $x1$ represents the weekly production quantity of the Collegiate backpacks and $x2$ denotes the weekly production quantity of the Mini backpacks.

(c) what are the constraints?

Answer) Constraints refer to the limitations or restrictions placed upon variables in a problem situation. In the context of the 'Back Savers' scenario, these constraints can pertain to resource requirements, availability of materials and labor hours, as well as sales capacity.

1) Available nylon: 5,000 square feet.
2) Nylon usage constraint: $3 \times x1 + 2 \times x2 \ \leq 5{,}000$
3) Labor time availability: 35 workers × 40 hours/worker = 1,400 labor hours, equivalent to 84,000 labor minutes.
4) Labor time usage constraint: $45 \times x1 + 40 \times x2 \ \leq 84{,}000$
5) Sales capacity constraints: $x1 \leq 1{,}000, x2 \leq 1{,}200$

, where $x1$ represents the weekly production quantity of the Collegiate backpacks and $x2$ denotes the weekly production quantity of the Mini backpacks.

(d) Write down the full mathematical formulation for this LP problem.

Answer)

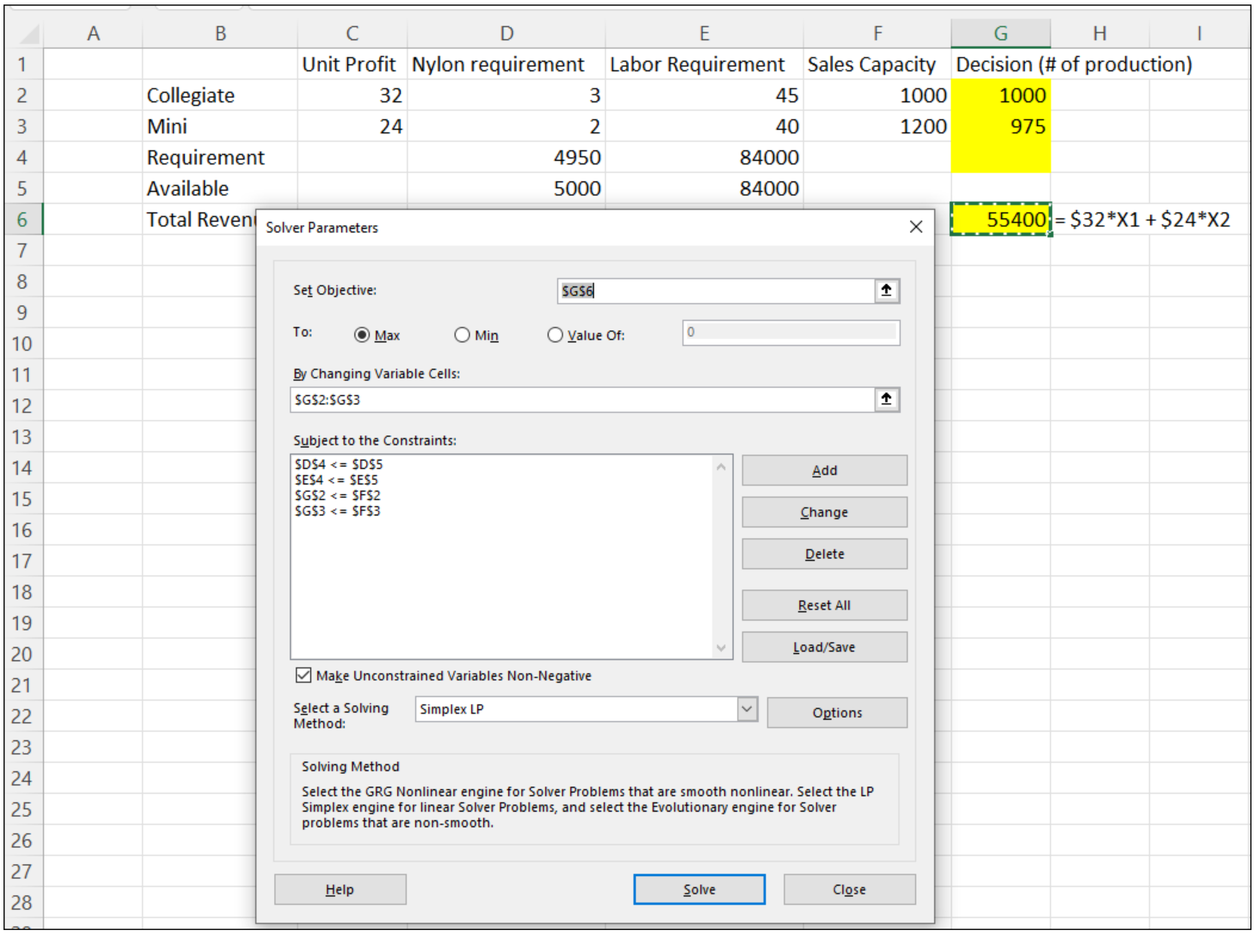
- Let
  $x1$ = Weekly production quantity of the Collegiate backpacks and
  $x2$ = Weekly production quantity of the Mini backpacks.
- Maximize total profit = $\$32 \times x1 + \$24 \times x2$,
- Subject to
  1) Nylon usage constraint: $3 \times x1 + 2 \times x2 \ \leq 5{,}000$
  2) Labor time usage constraint: $45 \times x1 + 40 \times x2 \ \leq 84{,}000$
  3) Sales capacity constraints: $x1 \leq 1{,}000, \ x2 \leq 1{,}200$

4) And $x1 \geq 0, x2 \geq 0$,
   $x1$ and $x2$ are integers.

Solution) $x1$=1,000 ; $x2 = 975$

By utilizing the Excel Solver tool, the optimal weekly production quantities were determined to be 1,000 units of $x1$ (Collegiate backpack) and 975 units of $x2$ (Mini backpack), resulting in a maximum weekly total profit of $55,400.

<Figure 1. Solver Results: Optimal Weekly Production for Collegiate and Mini Backpacks>



Problem 2.

(a) Define the decision variables.

Answer) In the Weigelt Corporation scenario, the decision variables are the daily production quantities of large, medium, and small products specifically at Plants 1, 2, and 3.

(b) Formulate a linear programming model for this problem.

Answer)

- Let
  $x1$ = Daily production of Large products at Plant 1.
  $x2$ = Daily production of Large products at Plant 2.
  $x3$ = Daily production of Large products at Plant 3.
  $x4$ = Daily production of Medium products at Plant 1.
  $x5$ = Daily production of Medium products at Plant 2.
  $x6$ = Daily production of Medium products at Plant 3.
  $x7$ = Daily production of Small products at Plant 1.
  $x8$ = Daily production of Small products at Plant 2.
  $x9$ = Daily production of Small products at Plant 3.

- Maximize total profit = $\$420 \times x1 + \$420 \times x2 + \$420 \times x3 + \$360 \times x4 + \$360 \times x5 + \$360 \times x6 + \$300 \times x7 + \$300 \times x8 + \$300 \times x9$
- Subject to
  1) Daily production capacity of Plant 1: $x1 + x4 + x7 \leq 750$
  2) Daily production capacity of Plant 2: $x2 + x5 + x8 \leq 900$
  3) Daily production capacity of Plant 3: $x3 + x6 + x9 \leq 450$

  4) Daily In-process storage capacity for Plant 1: $20 \times x1 + 15 \times x4 + 12 \times x7 \leq 900$
  5) Daily In-process storage capacity for Plant 2: $20 \times x2 + 15 \times x5 + 12 \times x8 \leq 1{,}200$
  6) Daily In-process storage capacity for Plant 3: $20 \times x3 + 15 \times x6 + 12 \times x9 \leq 750$

  7) Daily sales capacity for Large products: $x1 + x2 + x3 \leq 900$
  8) Daily Sales capacity for Medium products: $x4 + x5 + x6 \leq 1{,}200$
  9) Daily Sales capacity for Small products: $x7 + x8 + x9 \leq 750$

  10) Ensure uniform utilization of excess capacity between Plant 1 and Plant 2:
      $(x1 + x4 + x7)/750 = (x2 + x5 + x8)/900$
  11) Ensure uniform utilization of excess capacity between Plant 1 and Plant 3:
      $(x1 + x4 + x7)/750 = (x3 + x6 + x9)/450$
  12) And
      $x1 \geq 0, x2 \geq 0, x3 \geq 0, x4 \geq 0, x5 \geq 0, x6 \geq 0, x7 \geq 0, x8 \geq 0, x9 \geq 0$
      $x1$ ~ $x9$ are integers.

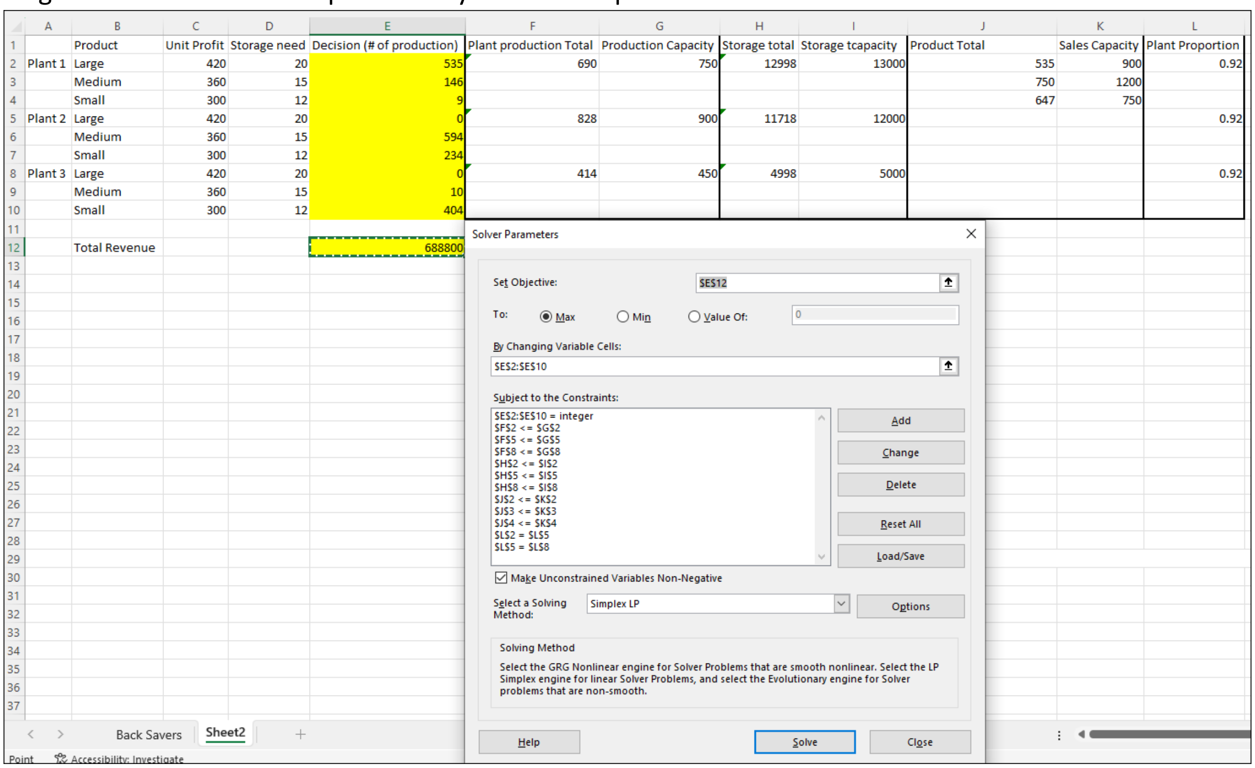
Solution)$x1$=535 ; $x2 = 0$; $x3 = 0$; $x4 = 146$; $x5 = 594$; $x6 = 10$; $x7 = 9$; $x8 = 234$; $x9 = 404$

By utilizing the Excel Solver program, the table below displays the recommended daily production of each product per plant to achieve a maximum total profit of $688,800.

<Table 1. Recommended Daily Production per Product and Plant for Maximum Profit>

	Large Product	Medium Product	Small Product
Plant 1	535	146	9
Plant 2	0	594	234
Plant 3	0	10	404

<Figure 2. Solver Results: Optimal Daily Production per Plant>



	A	B	C	D	E	F	G	H	I	J	K	L
1		Product	Unit Profit	Storage need	Decision (# of production)	Plant production Total	Production Capacity	Storage total	Storage tcapacity	Product Total	Sales Capacity	Plant Proportion
2	Plant 1	Large	420	20	535	690	750	12998	13000	535	900	0.92
3		Medium	360	15	146					750	1200	
4		Small	300	12	9					647	750	
5	Plant 2	Large	420	20	0	828	900	11718	12000			0.92
6		Medium	360	15	594							
7		Small	300	12	234							
8	Plant 3	Large	420	20	0	414	450	4998	5000			0.92
9		Medium	360	15	10							
10		Small	300	12	404							
11												
12		Total Revenue			688800							