Applied Electronics

Decision Analysis & Optimization

Identifying the Problem

Due to the change in demand and other economic factors, Applied Electronics is trying to find the most optimized production plant for its six plants in Mexico, Canada, Chile, Frankfurt, Austin and Japan. While some countries' production plants can satisfy the demand in that country, there are countries that either over or under produce. Additionally, in the case for moving the products, there are import duties that must be paid in order to transport products internationally.

	MX	CN	CL	FF	AU	JP
Capacity	22.0	3.7	4.5	47.0	18.5	5.0
Prod. Plan	17.2	2.6	4.1	38.0	14.0	4.0
Demand	3.0	2.6	16.0	20.0	26.4	11.9

	MX	CN	CL	FF	AU	JP
Prod. Cost	92.63	93.25	112.31	73.34	89.15	149.24
Import Duties (%)	60.0	0.0	50.0	9.5	4.5	6.0

Destination Price

Destination Price							
		Destination					
		MX	CN	CL	FF	AU	JP
Factory	MX	92.63	104.03	145.945	112.42985	107.79835	112.1878
	CN	160.2	93.25	148.875	113.60875	103.44625	111.845
	CL	186.696	112.31	112.31	135.97945	127.76395	133.3486
	FF	127.344	84.84	122.51	73.34	87.8403	91.0404
	AU	152.64	95.15	144.725	107.61925	89.15	106.999
	JP	252.784	162.24	236.36	177.6178	168.9558	149.24

Destination Price = Production Cost ⊙ (1 + Import Duties) + Shipping

Cost of Production Plan = $7844.52

*Import duty matrix is the row assembly of duties with diagonal being zeros

Import Duties (%)						
	MX	CN	CL	FF	AU	JP
MX	0.0	0.0	50.0	9.5	4.5	6.0
CN	60.0	0.0	50.0	9.5	4.5	6.0
CL	60.0	0.0	0.0	9.5	4.5	6.0
FF	60.0	0.0	50.0	0.0	4.5	6.0
AU	60.0	0.0	50.0	9.5	0.0	6.0
JP	60.0	0.0	50.0	9.5	4.5	0.0

Algorithm Implementation

Calculate Destination Cost → **Compute Penalty** → **Find Optimal Trade Pair** → **Locate (Broadcast) Resources** → **Iterate Step 2 to 4 until No Demand**

Calculate Destination Cost

- Destination cost is determined by three factors:
  - Production Cost
  - Import Duty
  - Shipping
- Vogel optimization requires destination cost matrix to find optimal production plan

Compute Penalty

- Find difference within each row and column for the lowest destination cost and the second lowest destination cost
- Assemble the values into row penalty and column penalty

Find Optimal Trade Pair

- Locate the highest penalty
- If the highest value is in row penalty, narrow down the cost matrix to such column, and vice versa
- The optimal cell has the lowest cost in the column (row)

Locate (Broadcast) Resources

- Locate resources in supply and demand vector
- If demand is higher than supply, transfer all supply to the buyer, and vice versa
- Broadcast the transaction in supply, demand, and transaction matrix

Iterate Step 2 to 4 until No Demand

- Update the selected column (row) to infinity
- Set all penalty values greater than a large value to zero
  - The goal is to prevent repetitive computation from previous steps
- Iterate until the demand is solved. Break if total supply is smaller than total demand

VAM based Production Plan: 100% Capacity

		Destination					
		MX	CN	CL	FF	AU	JP
Factory	MX	3.0	0.0	0.0	0.0	3.2	0.0
	CN	0.0	2.6	0.0	0.0	1.1	0.0
	CL	0.0	0.0	4.5	0.0	0.0	0.0
	FF	0.0	0.0	11.5	20.0	3.6	11.9
	AU	0.0	0.0	0.0	0.0	18.5	0.0
	JP	0.0	0.0	0.0	0.0	0.0	0.0

Total Cost: $7409.03

- In general, utilizing 100% of the plant capacity would result in the best results. It is around $400 lower in costs than the current production plan.
- The values on the last row indicate that the factory in Japan should be shut down as it does not contribute.
- The values in the fourth row indicates that Frankfurt has the highest value as it exports to multiple countries.
- The values in the third and fifth row indicates that Chile and Austin plants only serves itself and does not export to other countries.

VAM based Production Plan: 85% Capacity

		Destination					
		MX	CN	CL	FF	AU	JP
Factory	MX	3.0	0.0	4.125	0.0	5.88	0.0
	CN	0.0	2.6	0.0	0.0	0.545	0.0
	CL	0.0	0.0	3.825	0.0	0.0	0.0
	FF	0.0	0.0	8.05	20.0	0.0	11.9
	AU	0.0	0.0	0.0	0.0	15.725	0.0
	JP	0.0	0.0	0.0	0.0	4.25	0.0

Total Cost: $7898.51

- Running the production plants at a more realistic capacity at 85% does provide different insights. Compared to the 100% capacity, the total costs are higher. However, the 85% provides buffer for plants to adjust to abrupt changes.
- Compared to the current production plan of $7844.52 it is around $40 more expensive.
- Compared to before, the Japan plant is now a contributing plant and will ship to Austin.
- Mexico and Frankfurt are the highest contributors as they ship to two other countries each.

VAM based Production Plan w/o Chile: 100% Capacity

		Destination					
		MX	CN	CL	FF	AU	JP
Factory	MX	3.0	0.0	0.9	0.0	1.8	0.0
	CN	0.0	2.6	0.0	0.0	1.1	0.0
	CL	0.0	0.0	0.0	0.0	0.0	0.0
	FF	0.0	0.0	15.1	20.0	0.0	11.9
	AU	0.0	0.0	0.0	0.0	18.5	0.0
	JP	0.0	0.0	0.0	0.0	5.0	0.0

Total Cost: $7853.65

- Because the plant in Chile is the most difficult to support, if Applied Electronics were to shut this plant down, the total costs would be higher than that of having all production plants running at 100% but will be lower than that of having all plants run at 85%.
- Compared to the current production plan of $7844.52 it is around $10 more expensive.
- Austin would still be only able to support itself without any exporting.
- Frankfurt and Mexico will be the largest exporters shipping to 2 different locations each

VAM based Production Plan w/o Chile: 85% Capacity

		Destination					
		MX	CN	CL	FF	AU	JP
Factory	MX	3.0	0.0	7.95	0.0	5.88	0.0
	CN	0.0	2.6	0.0	0.0	0.545	0.0
	CL	0.0	0.0	0.0	0.0	0.0	0.0
	FF	0.0	0.0	8,05	20.0	0.0	11.9
	AU	0.0	0.0	0.0	0.0	15.725	0.0
	JP	0.0	0.0	0.0	0.0	4.25	0.0

Total Cost: $8027.17

- This option has the highest total cost out of the 4 different production plans
- Compared to the current production plan of $7844.52 it is around $120 more expensive.

Conclusion

- Vogel's approximation is an effective, simple method for finding solutions given linear constraints
- Compared to traditional heuristic approaches, Vogel's method often finds more optimal solutions is less iterations
- Under the optimal plan with 100% capacity, the company would save ~$435.49 compared to their original plan. However, under realistic operating capacities, the original plan is the most cost efficient.