

Final Project (Group)

Read the case Missouri Shoe Company provided below (the tables in the case are available electronically on Canvas). Build a mixed-integer linear program model to solve the problem.

Given the problem's size and complexity, python PuLP will be a better choice to solve the problem.

However, you are free to choose between Excel spreadsheet and python PuLP to solve the problem.

Submission Guidelines

You need to submit two files electronically under the "Assignment" section on Canvas:

- 1) *An electronic copy of your python or Excel spreadsheet file.*
- 2) *An electronic copy of a short, typed report that answers each case question. In the report, you should*
 - *Formulate (in math) linear program model for each problem (variables, objective function, constraints)*
 - *State any assumptions you made if the problem statement is not 100% clear about certain aspects of the problem*
 - *Present the optimal solution in an easy-to-communicate format*

*This is a group deliverable. **Work with your designated team members only.***

Missouri Shoe Company

The Missouri Shoe Co. (MSC) is a manufacturer of vintage footwear located in Missouri serving several large retailers within the state as well as smaller specialty stores.

MSC currently produces **two product lines**: shoes and boots. Each line consists of a variety of styles.

Large retailers generate the bulk of MSC's sales. MSC is responsible for delivering orders to the retailers' designated warehouses and stores. MSC delivers its products to **eight customer locations** in St Louis (4), Kansas City (2), Columbia (1), and Springfield (1). Projected 2021 quarterly sales of each product line at each retailer is given in the following table.

	STL1	STL2	STL3	STL4	KS1	KS2	COL	SPR
Shoes	8,000	6,500	7,500	0	9,500	2,300	7,000	6,000
Boots	2,200	0	1,200	900	4,500	0	2,000	3,200

MSC is currently unable to meet all projected demand. But it hopes to do so by 2021 through capacity expansion plans.

MSC currently has **two production facilities**, one is located in St Louis, and the other is located in Kansas City. Each production facility has one or more flexible production lines. A production line can produce any shoe or boot style. Changeover time between shoe styles is short.

Currently, the **St. Louis plant has two production lines**, while the **Kansas City plant has only one production line**. If a production line is dedicated to producing shoes only, it can produce 15,000 units per quarter. If a production line is dedicated to producing boots only, it can produce 9,000 units per quarter. Equivalently, 1 pair of shoes requires 1/15,000 of the capacity of a production line, and 1 pair of boots requires 1/9,000 of the capacity of a production line. If we normalize a production line's capacity to 1, then producing x1 pairs of shoes and x2 pairs of boots requires a capacity of $1/15,000 \cdot x1 + 1/9,000 \cdot x2$.

MSC is considering the following expansion possibilities that allow it to meet the projected quarterly demand in 2021:

- an expansion of its Kansas City plant to accommodate an additional production line.
- An opening of a new plant located in *Columbia, Springfield, or Independence, MO*.



The fixed (depreciation) and variable production costs of the facilities are as follows:

Plant	Production Lines	Fixed Cost [\$ per Quarter]	Variable Cost [\$ / pair]	
			Shoes	Boots
St. Louis	2	2,500,000	20	30
Kansas City	1	1,000,000	18	25
	2	1,700,000		
Columbia	1	1,000,000	15	20
	2	1,500,000		
Springfield	1	1,000,000	15	20
	2	1,500,000		
Independence	1	900,000	12	18
	2	1,300,000		

For example, at the St. Louis plant, each quarter, it costs \$2,500,000 to maintain two production lines; it costs \$20 to produce one pair of shoes and \$30 to produce one pair of boots. At the Kansas City plant, each quarter, it costs \$1,000,000 to maintain one production line and \$1,700,000 to maintain two production lines; it costs \$18 to produce one pair of shoes and \$25 to produce one pair of boots. If the company opens a new plant in Columbia, it costs \$1,000,000 to maintain one production line and \$1,500,000 to maintain two production lines; it costs \$15 to produce one pair of shoes and \$20 to produce one pair of boots.

The transportation distance [miles] from each plant (existing or proposed) to each customer location is as follows:

	STL1	STL2	STL3	STL4	KS1	KS2	COL	SPR
St. Louis	10	10	10	10	250	250	120	215
Kansas City	250	250	250	250	10	10	130	165
Columbia	120	120	120	120	130	130	10	170
Springfield	215	215	215	215	165	165	170	10
Independence	240	240	240	240	15	15	125	170

The transportation cost for shoes is \$0.03 per pair per mile and for boots is \$0.04 per pair per mile.

Questions:

1. (Base case) Make a comprehensive recommendation to MSC on:

- (a) Capacity expansion plan: whether the company should install a second production line at the Kansas City plant; whether the company needs to open new plants, and, if yes, in which of the three locations and how many production lines to set up at the chosen locations?

Note: Installing a second production line at the Kansas City plant and opening plants at new locations are not mutually exclusive choices. The company can choose to do both if needed.

- (b) Production plan: how much quantity of each of the two product lines (shoes and boots) to produce in each plant? **We can assume production plans can take continuous production quantities** because finding integer value solutions can be very time-consuming.
- (c) Distribution plan: which plant should supply which retail locations and how much of each product line to supply?

2. The per-pair revenue that MSC gets from selling its products is fixed: \$50 for shoes and \$80 for boots (the same revenue regardless of the retailer). Assume that the retailers' projected demand needs to be met in its entirety (per contractual or market share reasons). Modify the base case model accordingly. How does the optimal expansion plan under this scenario differ from the base case, and why?
3. The per-pair revenue that MSC gets from selling its products is fixed: \$50 for shoes and \$80 for boots (the same revenue regardless of the retailer). Assume that MSC does not need to meet the retailers' projected demand in its entirety (that is, MSC gets to choose how much to supply to each retailer within the demand projections). Modify the base case model accordingly. How does the optimal expansion plan under this scenario differ from the base case, and why?