Yuyi Zhang

Jun 20, 2020

Spring 2020 CPS Quarter Term B

Instructor: Danielle Mauro

Project 5:   
Linear Programming Models

ALY 6050\_Introduction to Enterprise Analytics

# **Introduction**

In project 4, we are going to discuss a plan of opening a new distribution center for a hardware company. There are four products will be distributed. Under certain budget, limited space and designated inventory requirement, the decision managers will need advices on quantity of each product that eventually generate the maximum profits. Also, managers will also need advices on whether increasing the budget or renting a larger warehouse to make the profits grow more. We are going to generate a linear programming model to solve the problem, as well as sensitivity report. Also, we are going to use while loop to answer the meeting budget questions.

# **Analysis**

## **Write the mathematical formulation of the problem**

Typically, there are 4 steps to develop an optimization model: define the decision variables, identify the objective function, identify constraints, and write mathematical expressions. In this case,

Step 1: Define decision variables. The decision variables are number of each product to distribute monthly, denoted as: .

Step 2: Identify objective functions. The company wants to maximum the profit by allocate different quantity of products. The cost and selling prices for each item are known, so the profit of each products would be:



*Table 1*. Profit per Unit

So, the objective function would be:

Step 3: Identify the constraints. From the information provided, we know that the cost budget is limited to $170,000. For the water pumps, we have the cost of 5 water pumps as $635. So, the cost per unit is $127. The space of warehouse is 82 shelves with 30ft long and 5 ft wide each, that equals to 12,300 ft in total. The space that each product needs would be: 5\*5 = 25 ft, 8\*5 = 40 ft, 5\*5 = 25 ft, 5\*5/5/4 = 1.25 ft. We need to instore pressure washer and Go-kart for more than 30% of the entire inventory. That is to say: , or . We also need to sell more than twice as many generators as water pumps. So we have: , or .

Step 4: Write the equations. To sum up what we have from step 1 to 3, we have:

## **Set up the linear programming formulation in an Excel workbook**

According to all the information provided and equations listed above, generate an Excel linear programming formulation as below. G11 would be the objective, B12: E12 are changing variables.

A screenshot of a cell phone

Description automatically generated

*Figure 1*. Linear Programming Formulation in Excel

## **Use the Excel Solver to solve the problem, and generate a Solver sensitivity report**

Here is the optimal solution shown in the spreadsheet as in Figure 2.

A screenshot of a cell phone

Description automatically generated

*Figure 2.* Optimal Solution

As well as the sensitivity report in Figure 3.



*Figure 3.* Sensitivity Report

## **Describe the optimal solutions obtained in the Word document. These will consist of the inventory level for all four products and the optimal monthly profit.**

The maximum profit is $141,812.93, obtained by distributing 0 pressure washer, 155 Go-karts, 238 generators and 119 water pumps per month.

## **One of the decision variables has an optimal value of zero. Use the Solver sensitivity report to determine the smallest selling price for that item so that this optimal zero solution value changes to a non-zero value.**

In the optimal solutions, the quantity of pressure washer is 0. The reduced cost in the sensitivity report is -109.653921. The rest reduced costs are 0 because they have positive final value. The final value of pressure washer is 0 because it’s economical reasons. So, we increase the selling price by $109.65, which is $609.65, then the optimal solution will change and will include a positive value for pressure washer.

## **Explain whether, in addition to the $170,000 allocated to the purchasing budget during the first month, the company should allocate additional money. If yes, calculate the amount of additional investment do you recommend, and how much should the company expect its net monthly profit to increase as a consequence of this increase**

For this problem, I set up a while loop in R, calculating what would be the effect when the budget is increased gradually. The basic budget is $170,000, then add up $100 each time until the point where profit doesn’t increase along the budget. We have:

A screenshot of a social media post

Description automatically generated

*Figure 4.* Increasing Budget

The result showing that when we increase the budget to $170,600, the profit stays at $142,050.24. This result aligns with the sensitivity report in Excel Solve. The shadow value of total cost is $0.5534, the Allowable Increase is 428.8. Multiply these two numbers we’ve got $237.31. Then the new profit would be: $141,812.93 + $237.31 = $142,050.24.



*Figure 5.* Sensitivity Report

Therefore, when we add $600 budget, no matter how we allocate the product, the profit will not change, mainly due to the limitation space of the warehouse.

## **Explain whether you recommend that the company should rent a smaller or a larger warehouse. In any case, indicate the ideal size of your recommended warehouse in square feet, and indicate how much this change in the size of the warehouse will contribute to the monthly profit.**

In this case I have set up another while loop to calculate the profit results when adding up space gradually. The basic space is 12,300. Then add up more at 150 each time until the profit stays put. We have:

A screenshot of a social media post

Description automatically generated

*Figure 6.* Increasing Space

The results showing that when the space reach up to 18,600, the profit stays in $165,401. We’ve got the same result from the sensitivity report too. The shadow price multiplies the allowable increase would be $3.88 \* 6,078.38 = $23,587.88. So, the new profit would be $141,812.93 + $23,587.88 = $165,400.81.

Therefore, when the company rent a larger warehouse to 18,600, the total profit would be $165,400.81.

# **Conclusions**

According the original data information we’ve known, set up a linear programming formulation in both Excel Solver and R, then we’ve got the same result that the profit of the new location would be $141,812.93, which is about $28,187 from the total cost. Then we tried to increase the budget and got a maximum profit as $142,050.24 due to the limited space in the warehouse, which is $27,950 from the total cost. Then we tried another way to rent a larger warehouse, then got a maximum profit as $165,400.81, which is $4,599 from the total cost. Therefore, no matter how we adjust the investment, the new location will not benefit under given constraints.

# Reference

1. Evans, J.(2012). *Statistics, Data Analysis and Decision Making*. Chapters 9 and 10.
2. Salazar, R. (2019). *Linear Programming with R*. Retrieved from: <https://towardsdatascience.com/linear-programming-in-r-444e9c199280>
3. Mic (2018). Linear programming in R. Retrieved from: <https://www.r-bloggers.com/linear-programming-in-r/>