Logo

Description automatically generated

**College of Professional Studies**

**Northeastern University San Jose**

**MPS Analytics**

**Course: ALY6050: Introduction to Enterprise Analytics**

**Assignment:**

Module 5 Project-  Maximizing Profit

**Submitted on:**

March 26, 2023

**Submitted to:**  **Submitted by:**

Prof: AZADEH MOBASHER NIKSHITA RANGANATHAN

# **ABSTRACT**

The best outcome in a given scenario with respect to a set of linear constraints is determined using the mathematical optimization technique known as linear programming. This method maximizes or minimizes a linear objective function under a set of linear constraints. LP is used in a wide range of fields including business, economics, engineering, and science.

The technique of linear programming involves several important components. The first component is the objective function. The objective function serves as the optimization problem's target. For example, if we are trying to maximize profits, then the objective function would be a linear equation that represents the total profit as a function of the decision variables.

The second component of linear programming is the decision variables. Decision variables are the unknown quantities in the objective function that we want to optimize.

The third component of linear programming is the constraints. Constraints are linear equations that limit the values of the decision variables. Constraints can represent limits on resources, demand, or production capacity. For example, if we are producing two types of products and we have a limited amount of raw material, the constraint would be the total amount of raw material used for both products cannot exceed the total amount available.

Linear programming has many real-world applications. In business, linear programming is used for optimizing production processes, resource allocation, and supply chain management. In finance, linear programming is used for portfolio optimization and risk management. In transportation, linear programming is used for optimizing routes and logistics. Linear programming is used in the healthcare industry to optimize patient care and allocation of resources.

**INTRODUCTION**

This assignment focuses on developing a linear programming model to help a northern hardware company make optimal decisions regarding its inventory management and distribution operations in a new distribution center in the southeast. The business plans to rent a warehouse and an adjacent office to distribute its four main products, which include pressure washers, go-karts, generators, and water pumps. The objective is to maximize the company’s net profit, given a purchasing monthly budget of $170,000 and certain constraints such as limited warehouse space and marketing requirements.

The assignment requires analyzing the costs of each product, includeing transportation, a’d determining the revenues generated from their sales. The costs associated with purchasing each of the products are given in Table 1, while Table 2 presents the selling prices per unit for each item.

Graphical user interface, table

Description automatically generated

Table

Description automatically generated

The available warehouse space, which has 82 shelves, also poses a significant constraint, as different products require different storage spaces. The marketing department’s requirements, such as allocating at least 30% of inventory to pressure washers and go-karts and selling at least twice as many generators as water pumps, further add to this problem.

The linear programming model will provide a mathematical framework to solve the inventory and distribution problem of the company. By optimizing the company’s net profit, the model will help the company to make informed decisions about the number of each product to purchase and distribute, ensuring that it remains within its purchasing budget and meets the marketing requirements while maximizing profits. By using a linear programming model, the company will be able to make data-driven decisions to optimize its profits while still meeting its marketing objectives.

Overall, this assignment aims to provide an opportunity to practice using linear programming to solve a real-world business problem.

**ANALYSIS & INTERPRETATION**

1. **Mathematical formulation**

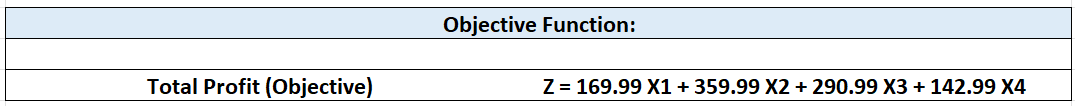
**Text

Description automatically generated**

**Figure 1- Decision variables**

The four steps to develop an optimization model are:

* **Define the decision variables:** The decision variables are the quantities being optimized or controlled in the problem. In this case, the decision variables are defined as X1, X2, X3, and X4, which represent the number of units of each product.



**EOQ (Economic Order Quantity) = square root of [(2 x annual demand x ordering cost per order) / (holding cost rate x unit cost)]**

**Figure 2- Objective function**

* **Identify the objective function:** The objective function is a mathematical representation of the goal of the problem. In this case, the goal is to maximize the total profit, which is expressed as a linear combination of the decision variables, where the coefficients are the profit margins for each product.

Profit margins are frequently represented as the difference between a product's selling price and its purchase price.

**Z = 169.99 X1 + 359.99 X2 + 290.99 X3 + 142.99 X4**

**Graphical user interface

Description automatically generated with medium confidence**

**Figure 3- Constraints**

* **Identify constraints:** Constraints are the limitations or restrictions that need to be considered while optimizing the objective function. In this case, there are four constraints: Total budget available, total space available, promotion 1, and promotion 2.
* **Write mathematical expressions:** The mathematical expressions for the constraints are:
  1. Total Budget Available: The total cost of purchasing all products should be less than or equal to the available budget of 170,000.

**330 X1 + 370 X2 + 410 X3 + 127 X4 ≤ 170,000**

* 1. Total Space Available: The total space required for all products should be less than or equal to the available space of 82 \* (5 \* 30) = 12,300 square feet.

**25 X1 + 40 X2 + 25 X3 + 1.25 X4 ≤ 12,300**

* 1. Promotion 1: The total profit contribution of the Pressure Washers and Go-Karts (0.7 X1 + 0.7 X2) should be greater than or equal to the total profit contribution of the Generators and Water Pumps (0.3 X3 + 0.3 X4).

**0.7 X1 + 0.7 X2 - 0.3 X3 - 0.3 X4 ≥ 0**

* 1. Promotion 2: The profit contribution of Generators should be at least twice that of the Water Pumps (X3 - 2 X4 ≥ 0).

**X3 - 2 X4 ≥ 0**

The non-negativity constraint is implied and is represented by the fact that X1, X2, X3, and X4 must be greater than or equal to 0.

1. **Linear programming formulation**

**Graphical user interface, table

Description automatically generated**

**Figure 4- Linear Programming Formulation in Excel**

The SUMPRODUCT function is used to determine the objective function, which is located in cell J9.

The decision variables X1, X2, X3, and X4 are in cells F9:I9 and the constraints are listed in rows 13 to 16.

1. **Excel Solver and Sensitivity Report**

**Graphical user interface, text, application

Description automatically generated**

**Figure 5- Optimal solution using Excel Solver**

* In Excel Solver, Set Objective cell if the objective function and Variable cells are the decision variables. We can define the constraints in Excel in the Constraints section of the Solver parameters dialog box.
* The unused resources column has been calculated by subtracting Constraint RHS value from Constraint LHS value.

**Table

Description automatically generated**

**Figure 6- Sensitivity report**

1. **Optimal values**

* The maximized profit value is 142,050.70.
* Optimal quantity values are 0, 155, 238, and 189 approximately for Pressure Washers, Go Karts, Generators, and Water Pumps respectively.

1. **Change the Optimal zero solution value to non-zero value**

**Table

Description automatically generated**

**Figure 7- Reduced cost for zero solution value**

The optimal quantity value of the Pressure washer is 0. According to the sensitivity report, the reduced cost for the pressure washer is negative, indicating that the current selling price of $499.99 is not enough to cover the cost of storage, resulting in a negative contribution to the overall profit.

However, if the company wants to store some units of the pressure washer, it needs to make changes to either the cost price or selling price. Since the cost price cannot be changed, the only option left is to increase the selling price by the allowable increase.

The new selling price of the pressure washer can be calculated by adding the absolute value of its reduced cost to the current selling price, which gives us **$499.99 + $110.07 = $610.06**. This is the smallest selling price at which the company can produce and store the pressure washer while still maintaining profitability.

When you change the selling price, the Z also changes to **280.06 X1 + 359.99 X2 + 290.99 X3 + 142.99 X4**

Graphical user interface, text, application

Description automatically generated

**Figure 8- Values after changing the SP**

The new optimal solution suggests that the company should stock 434 units of Pressure Washers, 0 units of Go Karts, 56 units of Generators, and 28 units of Water Pumps in the warehouse to maximize profit.

1. **Additional budget**

**Table

Description automatically generated**

**Figure 9- Checking for shadow price and allowable increase in Budget**

After reviewing the company's financial situation, I recommend that the company should allocate additional money to the purchasing budget during the first month. This is because increasing the budget can help the company acquire more inventory, which can lead to increased sales and profits in the future.

According to the sensitivity report, we have an allowable increase of 428.8. This means that the company can increase its initial budget of $170,000 by this amount to get a higher net monthly profit. The shadow price for the budget is $0.5576, which means that for every additional dollar invested in the budget, the company can expect to increase its net monthly profit by $0.5576.

Assuming that the company increases its budget to the allowable limit of $**170,428.8**, the new net monthly profit can be calculated as follows:

**New budget = $170,428.8**

**New net monthly profit = Profit + (Shadow price\* Allowable increase)**

**New net monthly profit = $142,050.70 + ($0.557648 x ($428.8))**

**= $142,289.82**

Graphical user interface, text, application, email

Description automatically generated

**Figure 10- Values after increasing the budget**

The values of X1, X2, X3, and X4 are 0, 154, 239, and 119 after increasing the budget.

1. **Smaller or larger warehouse**

**Table

Description automatically generated**

**Figure 11- Checking for shadow price and allowable increase in Space**

Based on the analysis, I recommend that the company should rent a larger warehouse.

The Allowable Increase value of 6078.37 square feet indicates that the company can increase the space available in the warehouse by this amount without affecting the current profit. Moreover, the Shadow Price value of 3.8415 indicates that for each additional square foot added to the warehouse, the profit will increase by around $3.8415.

The original Maximized Profit is $142,050.70 with an initial warehouse space of 12,300 square feet. By adding 6078.37 square feet, we can calculate the new Maximized Profit:

**Additional profit from new warehouse space = 3.8415 \* 6078.37 = $23,350.107**

**New Maximized Profit = Original Maximized Profit + Profit from new warehouse space**

**= $142,050.70+ $23,350.107 = $165,400.81**

Therefore, the ideal size of the recommended warehouse would be the initial warehouse space of 12,300 square feet plus the Allowable Increase of 6078.37 square feet, which results in an ideal size of **18378.38 square feet**.

**Graphical user interface, text, application, email

Description automatically generated**

**Figure 12- Values after increasing the space**

After increasing the space, the values suggest that the company should focus on stocking Go-karts in the new location while avoiding stocking Pressure washers, Generators, and Water pumps.

**CONCLUSION**

In this assignment, the Linear Programming model helped the company to maximize its profits by identifying the optimal values of decision variables subject to the given constraints. Additionally, we have used the sensitivity report to identify areas where the company can improve its profits further, such as increasing the selling price of pressure washers, increasing thitsudget, or renting a larger warehouse.

The project has provided valuable insights to the company on how to manage its resources effectively and efficiently to maximize its profits. It has also demonstrated the usefulness of Linear Programming in solving real-world business problems.

**REFERENCES**

Bluman, A. G. (2018). Elementary Statistics, 10th ed. McGraw Hill.

Kabacoff, R. I. (2011). R in action: Data analysis and graphics with R. Manning Publications Co.

Home - RDocumentation. (n.d.). <https://www.rdocumentation.org/>