ALY 6050: INTRO TO ENTERPRISE ANALYTICS

Module 5 Project

Using Linear Programming Models to maximize profits

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Introduction

This paper will discuss how to optimize profit, apply linear programming in this project. This will enable you to comprehend business difficulties, interpret company needs into mathematical terms, and solve problems using linear algebra. The feasibility of constructing a new distribution center in the south is being investigated by a hardware store in the north. The business intends to lease a warehouse and an adjacent office and supply the necessary supplies to the nearby stores. Water pumps, pressure washers, go-karts, and generators will be the first four main products offered by the company. By using linear programming to find the most effective solution, you will assist the business in boosting profits.

For the aim of purchasing these items for the new site, the firm has put aside a budget of $170,000 every month. The 82 shelves in the warehouse are each 30 feet long by 5 feet wide. Pallets of varying sizes are used to store the various items. Each go kart is stored on an 8 by 5 foot pallet as opposed to the pressure washers and generators, which are each housed individually on a 5 by 5 foot pallet. Further, Four cases of water pumps are kept on a 5 by 5 foot pallet. In order to promote the brand, the marketing division claims that pressure washers and go-karts should account for at least 30% of the business's inventory. Another goal of the corporation is to sell at least twice as many generators as water pumps. In an effort to boost the company's net profit, analysis will be conducted using a linear programming model each month.

The tabular statistics below indicate the cost and selling price of four different products: a pressure washer, a go-kart, a generator, and a water pump. With the data at our disposal, we were able to calculate the profit margins for each of these items. Despite the fact that a case of water pumps contains five units, it should be noted that the price mentioned in the table is for just one.

Part 1-4			
Product	**Cost**	**Selling price**	**Profit**
Pressure washer	330	499.99	169.99
Go-kart	370	729.99	359.99
Generator	410	700.99	290.99
Water Pump	127	269.99	142.99

Figure 1 – using cost and selling price to determine profit

Analysis

1. Mathematical formulation

<u>Decision Variables</u>: A deciding aspect would be the quantity of each product.

x1 □ Count of Pressure Washer
x2 □ Count of Go-karts
x3 □ Count of Generators
x4 □ Count of Water Pumps

<u>Objective Function</u>: Maximize Profit and the Profit Is referred from fig1

Total Profit = x1 * 169.99 + x2 * 359.99 + x3 * 290.99 + x4 * 142.99 = Sum and Product of the quantities.

<u>Constraints:</u>

Constraint No1: Maximum monthly budget allotted for purchasing the goods is $170,000.

x1 * 330 + x2 *370 + x3 * 410 + x4 *127 <= **170000**

Constraint2: The distribution of each product's quantity depends on the size of the available shelves. In total, there are 82 shelves, each measuring 30 feet long by 5 feet wide. 12,300 square feet are available in total. (30 * 5 = 150 and 150 * 82 = 12300).

x1 * 25 + x2 * 40 + x3 * 25 + x4 * 1.25 <= **12300**

Constraint No 3: Allocation of minimum 30% of inventory to pressure washers and Go Karts

x1 + x2 >= 0.3 * (x1 + x2 + x3 + x4)

Constraint4: Target to sell at least twice as many generators as water pumps.

x3 >= 2 * x4

Constraint5: Quantity of each product is a non-zero positive number.

x1, x2, x3, x4 >= 0

2. Linear programming formulation

To carry out a linear programming work, we lack the requisite decision variables, objective functions, and constraints. So, we use Excel's solver to establish the ideal amounts of each product that meet all needs and provide the most profit.

Variables	Optimal Qty
x1	**0**
x2	**155.179067**
x3	**237.7692613**
x4	**118.8846306**

Figure 2 – Optimal inventory for each product

3. Sensitivity report using Excel Solver

Figure 3 displays the answer report generated by Excel Solver. It also displays the recommended doses for each product together with the expected outcome for the given objective function.

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$C$9	x1 Optimal Qty	0	0	Contin
$C$10	x2 Optimal Qty	155.179067	155.179067	Contin
$C$11	x3 Optimal Qty	237.7692613	237.7692613	Contin
$C$12	x4 Optimal Qty	118.8846306	118.8846306	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$16	constrain1 Optimal Qty	170000	$C$16<=$E$16	Binding	0
$C$17	constrain2 Optimal Qty	12300	$C$17<=$E$17	Binding	0
$C$18	constrain3 Optimal Qty	155.179067	$C$18>=$E$18	Not Binding	1.629179331
$C$19	constrain4 Optimal Qty	237.7692613	$C$19>=$E$19	Binding	0
$C$20	constrain5 Optimal Qty	0	$C$20>=0	Binding	0
$C$21	constrain6 Optimal Qty	155.179067	$C$21>=0	Not Binding	155.179067
$C$22	constrain7 Optimal Qty	237.7692613	$C$22>=0	Not Binding	237.7692613
$C$23	constrain8 Optimal Qty	118.8846306	$C$23>=0	Not Binding	118.8846306

Figure 3 – Maximum profit with optimal inventory: excel solver output

The quantity of each choice variable and constraint that is optimum as well as the lower and upper bounds of the goal and constraint coefficients, as well as the ranges in which they will not change, are presented below.

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$C$9	x1 Optimal Qty	0	0	169.99	110.07152	1E+30
$C$10	x2 Optimal Qty	155.17907	0	359.99	205.84024	76.738786
$C$11	x3 Optimal Qty	237.76926	0	290.99	98.204905	131.86641
$C$12	x4 Optimal Qty	118.88463	0	142.99	196.40981	89.119657

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$C$16	constrain1 Optimal Qty	170000	0.55764834	170000	428.8	56225
$C$17	constrain2 Optimal Qty	12300	3.84150284	12300	6078.3784	30.946882
$C$18	constrain3 Optimal Qty	155.17907	0	0	1.6291793	1E+30
$C$19	constrain4 Optimal Qty	237.76926	-33.683391	0	27.916667	974.12019
$C$20	constrain5 Optimal Qty	0	-110.07152	0	434.09982	0
$C$21	constrain6 Optimal Qty	155.17907	0	0	155.17907	1E+30
$C$22	constrain7 Optimal Qty	237.76926	0	0	237.76926	1E+30
$C$23	constrain8 Optimal Qty	118.88463	0	0	118.88463	1E+30

Figure 4 – Sensitivity report: excel solver output

4. Optimal Solutions

In order to maximize revenues, keeping an inventory of 158 go-karts, 237 generators, and 118 water pumps is necessary, with a target profit of $142,050. It's crucial to remember that $27,950 of the original $170,000 budget was not utilized.

The sensitivity report offers useful data that may be used to establish the price range for each product. Focusing on the go-kart product, for instance, it can be shown that the ideal quantity does not vary regardless of whether the profit value rises or falls by $205.84 or $76.72. To determine a suitable selling price range for go-kart items, these data may be used.

5. Minimum selling price for non-zero quantity of Pressure washer

The permissible range for profit increase and loss in the aforementioned case, when the ideal quantity of pressure washer is zero, is between 110.071 and 1E+30, respectively. In order to calculate the selling price, it is therefore possible to slightly stray from this range. It is regarded as fair to modify the selling price in light of a reasonable profit rise of 110.1 and a commensurate selling price increase of 610.09.

Part 5 - Minimum selling price			
Product	**Cost**	**Selling price**	**Profit**
Pressure washer	**330**	**610.09**	**280.09**
Go-kart	**370**	**729.99**	**359.99**
Generator	**410**	**700.99**	**290.99**
Water Pump	**127**	**269.99**	**142.99**

Figure 5 – Calculation of updated selling price

The solution is also used to find the optimal quantity of each product, resulting in 434 non-zero numbers for pressure washers. This means that 610.09 would be our minimum selling price.

Variables	Optimal Qty
x1	**434.0998152**
x2	**0**
x3	**56.48798521**
x4	**28.24399261**

Figure 6 – Non-zero value of pressure washer quantity

6. Feasibility check for further budget allocation

It was found that there was a surplus of $27,937 from the initial budget of $170,000 available for additional inventory purchases after computing the ideal values for each inventory variable. To accommodate any additional goods, it is crucial to make sure that the 12,300 square feet of storage space are used to their fullest. It may be possible to use the unused budget to boost earnings from $142,050 to $142,063, but given the limited amount of space available, it is best to refrain from doing so.

Objective Function	142063.0645		
constrain1	170000	<=	170000
constrain2	12300	<=	12300
constrain3	434.0998152	>=	155.6495
constrain4	56.48798521	>=	56.48799
constrain5	434.0998152	>=	0
constrain6	0	>=	0
constrain7	56.48798521	>=	0
constrain8	28.24399261	>=	0

Figure 7 – Constraints for both scenarios

7. Feasibility check for further space allocation

When we use the Excel solution, the constraint's total square footage changes from 12300 to 20,000 square feet. Profits were increasing at 18300, as can be shown, but the desired stock level for each product was impractical. We can earn the maximum money out of the warehouse's 18300 total square feet, or $165099.72, with an inventory of 455 go-karts, 3 generators, 1 water pump, and no pressure washer.

Part 7 - Optimal warehouse size	
Warehouse area (SqFt)	**Profit $**
12300	142050.7
13000	144739.755
14000	148581.8
15000	152422.76
16000	156264.26
17000	160105.76
18000	163947.26
18300	**165099.72**
Note: This table is generated manually applying solver on the left most table and changing area	

Figure 8 – Optimal warehouse size and profit calculation

Conclusion

- In order to optimize earnings with a $170,000 budget, it is best to have an inventory of 158 go-karts, 237 generators, and 118 water pumps. This will yield a maximum profit of $142,050. It is essential to remember that pressure washers must maintain a minimum selling price of $610.09 in order to retain some inventory of the product. It is not possible to spend any extra money on merchandise due to space restrictions.
- The greatest profit feasible is $165099.72 when 18300 square feet of warehouse space is taken into account. This can be done by keeping a supply of 455 go-karts, 3 generators, and 1 water pump on hand, but not a pressure washer.

References:

- Young, C., PE. (2022, April 22). *Constrained Optimization in Excel – Maximize Open Channel Flow*. EngineerExcel. https://engineerexcel.com/constrained-optimization-in-excel/

- *Excel Solver - Add, change or delete a Constraint*. (2015, April 7). Solver. https://www.solver.com/excel-solver-add-change-or-delete-constraint.