INTRODUCTION TO ENTERPRISE ANALYTICS

ALY6050, WINTER 2020

MODULE 5 PROJECT ASSIGNMENT

LINEAR PROGRAMMING MODEL

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Introduction

The assignment gave us an opportunity to perform optimization of profits and costs by using a linear programming model on a company's inventory. Since, the company is planning on opening its store at a new location, the cost and profit for the company is optimized by considering decision parameters, objective functions and constraints. We have used R programming in order to perform and implement the optimal profit and cost for the company.

Analysis

<u>Part I – Mathematical Formulation</u>

- The Northern Hardware company has planned of opening a new center, and plans to start with initial four od its products. Moreover, the company has a budget of $175000 that it would be investing for its new location. Considering, The cost price and selling price for the products, we have calculated the profits. (1)

	Cost	Price	Profit
Pressure Washer	365	479.99	114.99
Go-kart	368	629.99	261.99
Generator	411	599.99	188.99
Caseof 5 waterpumps	567	369.99	-197.01

Fig.1: Cost price, selling price and profits for the products

- Also, the company has a warehouse containing 80 shelves where each shelf has dimensions of 30ft by 5ft. We know that, 33% of the inventory has been allocated for pressure washers and Go Karts. The company intends on selling twice as many generators as water pumps for promotional purposes.
- Using the concept of linear programming, where the mathematical model is formulated to find the optimal solution to the problem by considering the constraints and decision variables. (2)
- An advantage of linear programming model is it structures the entire processing, improves efficiency and makes the problem tractable. Hence, this approach is used in various applications like, Transportation problems and production scheduling where the optimal solution is used.
- The decision variables are inputs that represent the decisions which the company manager should make in order to achieve the required objective. We have considered, the following decision variables for mathematical formulation:

  X1 – Number of pressure Washer
  X2 – Number of Go-Karts
  X3 – Number of Generators
  X4 - Case of 5 Water pumps

  The objective function for maximizing the profit is as follows:

  $Z = 114.99\, X1 + 261.99\, X2 + 188.99\, X3 – 197.01X4$

  We have considered the following constraints, for linear formulation:

  Budget: $365\, X1 + 368\, X2 + 411\, X3 + 567\, X4 <= 175000$, where the coefficients denote the cost price of products, since we have to minimize the budget

Size: 25 X1 + 25 X2 + 40 X3 + 30 X4 <= 2400, where the coefficients on left hand side denote the area for pallets for storing the products and right hand side, denotes the total area, given by:

Total Space = 80 * 30 = 2400

Inventory: 2 X3 – X4 >= 0, since the company intends to sell twice as many generators as water pumps

Space Allocation: X1 + X2 >= 0.33*sum (X1 + X2+ X3 + X4), since 33 % of the inventory has been assigned to pressure washers and Go Karts

Part II – Constraint Matrix

- Performing the implementation in R Studio, involved installing of *lpsolve* package. This package is used for solving linear and integer problems. (2)
- The coefficients of all the considered decision variables were stored in a variable using:

```
#Coefficients of decision variables

f_coeff_decision <- c(114.99,261.99,188.99,-197.01)
```

Fig.2: R Code for Coefficients of Decision Variables

- The constraints on left hand side of equation, were defined using the constraint matrix:

```
f_constraint_lhs <- matrix (c(365,368,411,567,
                              5,8,5,6,
                              1,1,0,0,
                              0,0,2,-1), nrow=4, byrow=TRUE)
```

Fig.3: Constraint Matrix in R

- The directions to the inequalities were defined using the following function:

```
#Direction of Constraints

f_direction <- c("<=", "<=",">=",">=")
```

Fig.4: R Code showing directions in inequality

- The Right hand side of the constraints have been defined as follows:

```
a<-maximum_profit_temp$solution
b<-0.33*sum(a)
f_right_hand_side <- c(175000,2400,b,0)
maximum_profit_temp=lp("max",f_coeff_decision,f_constraint_lhs,f_direction,f_right_hand_side)
maximum_profit_temp$solution
Maximum_Profit=lp ("max", f_coeff_decision, f_constraint_lhs, f_direction, f_right_hand_side)
Maximum_Profit$solution
Maximum_Profit$objval
summary(Maximum_Profit)
```

Fig.5: R Code showing the Right Hand Side of Constraints

- As we can see, that 33 % of the company's inventory has been allocated for pressure washers and Go Karts. Also, the company intends on selling twice as many generators as water pumps, hence we have stored the profits of values of pressure washers and Go Karts in a variable, “a” and used the given condition in variable, “b” as can be seen in the code above. (2)

- On the basis of the given conditions, the optimal value of monthly profit was calculated to be 84376.2 and the optimal size of inventory should be 475.54 units. The optimal level of inventory can be calculated as:

```
> f_direction <- c("<=", ">=",">=",">=")
> Size_Inventory=lp ("max", f_coeff_decision, f_constraint_lhs, f_direction, f_right_hand_side)
> Size_Inventory$objval
[1] 124587.6
> Size_Inventory$solution
[1]   0.0000 475.5435   0.0000   0.0000
```

Fig.6: R Code for Optimal Size of Warehouse

Part III- Sensitivity Analysis

- We have implemented the sensitivities for finding the solver sensitivity to calculate the smallest selling price for the item. (2)

```
> # Get sensitivities
> lp ("max", f_coeff_decision, f_constraint_lhs, f_direction, f_right_hand_side, compute.sens=TRUE)$sens.coef.from
[1] -1.000000e+30  2.283840e+02  1.637437e+02 -1.000000e+30
> lp ("max", f_coeff_decision, f_constraint_lhs, f_direction, f_right_hand_side, compute.sens=TRUE)$sens.coef.to
[1] 148.596 302.384 245.000 226.788
```

Fig.7: R Code for Sensitivity Analysis

- Sensitivity analysis determines, the outcomes of input parameters on the output parameters.
- Using the formula, Profit = Selling Price – Cost Price,
The selling price for pressure washer was observed to be the smallest.

```
> ###Duals##
> lp ("max", f_coeff_decision, f_constraint_lhs, f_direction, f_right_hand_side, compute.sens=TRUE)$duals
[1]    0.000   37.798  -40.394    0.000  -33.606    0.000    0.000 -423.798
> lp ("max", f_coeff_decision, f_constraint_lhs, f_direction, f_right_hand_side, compute.sens=TRUE)$duals.from
[1] -1.000000e+30  1.018624e+03  7.693370e+01 -1.000000e+30 -4.604587e+02 -1.000000e+30 -1.000000e+30 -1.000000e+30
> lp ("max", f_coeff_decision, f_constraint_lhs, f_direction, f_right_hand_side, compute.sens=TRUE)$duals.to
[1] 1.000000e+30 2.577545e+03 3.000000e+02 1.000000e+30 5.991045e+01 1.000000e+30 1.000000e+30 1.625148e+02
```

Fig.8: R code for Calculating Duals

The duals are used for retrieving the values of reduced and optimized costs.

Part IV- Allocation of money

- After performing analysis, it was observed that the company should allocate additional amount apart from the budget of $175,000.

```
> # Allocation of additional money
> f_direction <- c(">=", "<=",">=",">=")
> Maximum_Profit_Additional=lp ("max", f_coeff_decision, f_constraint_lhs, f_direction, f_right_hand_side)
> Maximum_Profit_Additional$objval
[1] 83180.89
> Maximum_Profit_Additional$solution
[1]  65.49866  66.52991 308.05349   0.00000
```

Fig.9: Allocation of additional amount

- It can be observed that the company should allocate, $65.49, $66.62 and $308.05 for Pressure Washer, Go-Kart and generators. On allocating the amount, the company can get a net monthly profit of $83180.89 with this increase. (3)

Part V- Renting of Warehouse

- The inventory size calculates to 124587.6 and the actual size is 2400. The change in both the sizes amounts to 122187, which shows that the company can rent a larger warehouse. (3)

```
> f_direction <- c("<=", ">=",">=",">=")
> Size_Inventory=lp ("max", f_coeff_decision, f_constraint_lhs, f_direction, f_right_hand_side)
> Size_Inventory$objval
[1] 124587.6
> Size_Inventory$solution
[1]   0.0000 475.5435   0.0000   0.0000
```

Fig.10: R Code for Renting the warehouse

- The ideal size of the warehouse should be 122187 sq.ft which will help in accommodating and storing more amounts of products and increase the company's profits.

CONCLUSION

1. We have formulated the mathematical model using the decision variables and constraints like budget, space allocation and inventory for maximizing the cost and profits for the company.
2. Using the constraint matrix in R studio, we have formulated the linear programming model.
3. On the basis of the given condition, the optimal profit was calculated to be 84376.2 and the optimal size of inventory should be 475.54 units.
4. On performing analysis for calculating allocation of money, It can be observed that the company should allocate, $65.49, $66.62 and $308.05 for Pressure Washer, Go-Kart and generators. The company can get a net monthly profit of $83180.89 with this increase.
5. The ideal size of the warehouse should be 122187 sq.ft which will increase the company's profits.

Reference

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