Profit Optimization of Home Needs

BAN 630 Optimization Methods for Analytics

Spring 2023

March 12, 2023

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Summary

This report outlines how Home Needs, a small home appliances company based in California, tackled their ordering problem. They sought to optimize their ordering process to ensure they have enough inventory to meet customer demand and maximize profits.

Using an integer programming approach, Home Needs conducted a prescriptive analysis to determine the optimal quantity of units to order from their supplier for each category of home appliance. The model considered various factors, constraints, and decision variables to optimize their ordering process. Sensitivity analyses were also conducted to determine how changes in different factors would impact the optimal solution.

As a result of the prescriptive analysis, Home Needs was able to maximize their profits by ordering the right quantity of each appliance category. The company was able to make data-driven decisions, improve their ordering process, and achieve their goal of optimizing their profit. The analysis allowed Home Needs to make informed decisions and adjust their strategy accordingly to achieve their goals.

Introduction

Company

The company is a small family-owned store of home appliances based in California. The store has been in operation for several years and has established a loyal customer base. The company specializes in selling high-quality home appliances such as refrigerators, washing machines, air conditioners, etc.

In order to ensure that the company remains profitable, the store manager wants to identify the optimal number of units of home appliances to order from the supplier. The manager wants to make sure that the company orders only the number of units that will satisfy the demand, so that the store does not have a surplus of inventory that will not sell.

To achieve this goal, the store manager will need to gather data on customer demand for different home appliances based on last year’s sales, taking into account factors such as seasonal trends and changes in consumer preferences. The manager will also need to analyze the costs of ordering as well as the profit margins for each appliance.

Problem Statement

The company has data from the previous year's sales that indicates the demand for each category of home appliances such as microwaves, air conditioners, fans, etc. Based on an analysis of last year's sale data, the company is projecting a 20% increase in demand across all categories of home appliances. The company aims to order only enough inventory to meet demand and avoid carrying excess inventory at the end of the year while staying within the warehouse capacity of 3600 sq. ft. The company is willing to increase its budget to $200,000 for this purpose, as last year's total cost for ordering from the supplier was $159,400.

Therefore, the problem statement is how to identify the optimal number of units of home appliances to order from the supplier, taking into account the available budget, the projected increase in demand, the warehouse capacity, and the company's objective of maximizing profit.

Proposed Solution

The proposed solution to optimize the number of order quantity of home appliances involves using pure integer linear programming, which can be facilitated by Excel's Solver. We will use the simplex method to perform optimization.

The first step in this process is to gather and analyze data from the previous year's sales to determine the demand for each category of home appliances. This data will help us to determine the projected increase in demand across all categories of home appliances.

Next, we will use the information on the available budget and warehouse capacity to determine the maximum number of units of each category of home appliances that can be ordered. This will help us to establish the constraints for the optimization problem.

We will then formulate the optimization problem as a pure integer linear programming problem. The objective function will be to maximize profit, which will be determined by subtracting the total cost per unit from the total revenue generated per unit. The decision variables will be the number of units of each category of home appliances to order.

Using Excel's Solver, we will use the simplex method to solve the optimization problem and determine the optimal number of units of each category of home appliances to order. This will be the number of units that maximizes profit while taking into account the constraints of the available budget and warehouse capacity.

Once we have determined the optimal number of units of each category of home appliances to order, we can place the order with the supplier. This will ensure that the company meets the projected increase in demand while avoiding excess inventory at the end of the year.

Overall, the use of pure integer linear programming with Excel's Solver and the simplex method will provide an efficient and effective solution to the optimization problem of determining the right number of units of home appliances to order.

Main Chapter

Data Collection

We created a hypothetical scenario and generated data specifically for our analysis. This data includes sales amount, sales quantity, total cost, cost per unit, selling price per unit, order quantity, profit per unit, and total profit for each appliance.

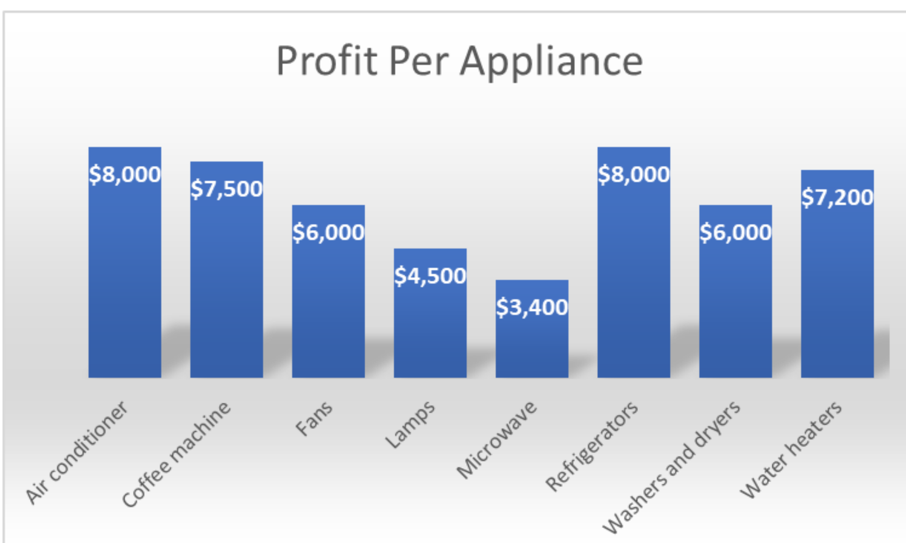
Product Category	Sales Amt ($)	Sales Quantity	Total Cost ($)	Cost Per Unit ($)	Sale Price Per Unit ($)	Order Quantity	Profit Per Unit ($)	Total Profit ($)
Air conditioner	$50,000	100	$42,000	$350	$500	120	$150	$8,000
Coffee machine	$20,000	200	$12,500	$50	$150	250	$100	$7,500
Fans	$15,000	500	$9,000	$15	$30	600	$15	$6,000
Lamps	$12,000	400	$7,500	$15	$30	500	$15	$4,500
Microwave	$25,000	150	$21,600	$120	$200	180	$80	$3,400
Refrigerators	$40,000	80	$32,000	$400	$600	100	$200	$8,000
Washers and dryers	$30,000	120	$24,000	$200	$350	150	$150	$6,000
Water heaters	$18,000	90	$10,800	$120	$200	120	$80	$7,200

We gathered data on the company's capacity by considering the length and width of each product, taking into account the possibility of stacking (*Microwave Sizes: A Guide to Common Dimensions*, n.d.).

Products	Dimensions (inches)
Air conditioner	30 x 36 x 24
Coffee machine	16 x 9 x 14
Fans	24 x 24 x 8
Lamps	10 x 10 x 20
Microwave	21 x 18 x 14
Refrigerators	32 x 36 x 70
Washers and dryers	27 x 26 x 42
Water heaters	18 x 18 x 28

Data Analysis

The below graph shows the profit per appliance for the year 2022.



The data analysis for determining the maximum value for the capacity and budget constraints involved several calculations. To calculate the maximum value for the capacity constraint, we first calculated the area for each appliance in square feet. For smaller appliances that can be stacked, such as coffee machines and fans, we divided the total area per appliance by the number of units in a stack to obtain the area required per appliance (Barrymore, n.d.).

Products	**Dimensions (inches)**	**Length (ft)**	**Width (ft)**	**Area (sqft)**	**No of units stacked**	**Area after stacking (sqft)**
Air conditioner	30 x 36 x 24	2.5	3.0	7.5	2.0	3.8
Coffee machine	16 x 9 x 14	1.3	0.8	1.0	2.0	0.5
Fans	24 x 24 x 8	2.0	2.0	4.0	3.0	1.3
Lamps	10 x 10 x 20	0.8	0.8	0.7	2.0	0.3
Microwave	21 x 18 x 14	1.8	1.5	2.6	2.0	1.3
Refrigerators	32 x 36 x 70	2.7	3.0	8.0	1.0	8.0
Washers and dryers	27 x 26 x 42	2.3	2.2	4.9	1.0	4.9
Water heaters	18 x 18 x 28	1.5	1.5	2.3	1.0	2.3

To identify the maximum order quantity, we are considering the storage capacity of each category by dividing the total available storage area by area required for each unit of a particular category of appliance.

Maximum Order Quantity Based on Storage Capacity

Products	**Area (sqft)**	**Total Area (sqft)**	**Maximum Order Quantity**

Air conditioner	3.8	3,600	947
Coffee machine	0.5	3,600	7,200
Fans	1.3	3,600	2,769
Lamps	0.3	3,600	12,000
Microwave	1.3	3,600	2,769
Refrigerators	8	3,600	450
Washers and dryers	4.9	3,600	735
Water heaters	2.3	3,600	1,565

To calculate the maximum value for the budget constraint, we considered the previous year's aggregated total cost of appliances and applied an increase of 25% year over year. This resulted in a budget constraint of $200,000.

In order to balance the decision-making process and avoid the model favoring products with higher profit margins and less storage space requirements, we applied minimum quantity constraints based on last year's sales quantity. This ensures that we order enough of each product to meet customer demand. Additionally, we applied maximum quantity order constraints to products that occupy less space to optimize the use of storage space.

To calculate the minimum order quantity for this year, we increased the previous year's sales quantity by 20% to forecast a better year than the previous.

Minimum Order Quantity Constraints

Products	Sales Quantity (last Year)	Expected Percent Increase	Minimum Order Quantity
Air conditioner	100	20.00%	120
Coffee machine	200	20.00%	240
Fans	500	20.00%	600
Lamps	400	20.00%	480
Microwave	150	20.00%	180
Refrigerators	80	20.00%	96
Washers and dryers	120	20.00%	144
Water heaters	90	20.00%	108

By considering these data analysis calculations, we can optimize the number of units of each category of home appliances to order while staying within the capacity and budget constraints.

Optimization Modeling

Step one in the optimization process is to identify the decision variables and input variables. In this case, the optimal number of units to order depends on profit per unit sold, cost incurred for each unit, the storage area required in square feet per unit, and previous year's sales quantity to act as a benchmark for demand in the coming year - the identified input variables.

Input variables	Definition
Profit per unit	The amount of profit per unit of appliance sold. Calculated by the difference between cost per unit and sale price per unit.
Cost per unit	The cost incurred by the business for each unit of appliance in inventory.
Area per unit	The amount of space required to store one unit of appliance, measured in square feet.
Sales quantity	Previous year's sales figure representing the number of units of each appliance sold.

The decision variable in this case would be the number of units to procure from the supplier.

Decision Variable	Definition
X_1	No of air conditioners ordered
X_2	No of coffee machines ordered
X_3	No of fans ordered
X_4	No of lamps ordered
X_5	No of microwaves ordered
X_6	No of refrigerators ordered
X_7	No of washers and dryers ordered
X_8	No of water heaters ordered

The objective function is to maximize the profit by obtaining the optimal quantity of each appliance type.

Objective Function	Definition
Max. $150X_1 + 100X_2 + 15X_3 + 15X_4 + 80X_5 + 200X_6 + 150X_7 + 80X_8$	The maximum amount of profit as calculated by the sum product of procured units and profit per unit for each product in the Home Needs product portfolio.

We are constrained by the capacity to store appliances in our warehouse, by a budget constraint, by minimum order quantity for each quantity of products to ensure that we meet the new demand, and finally by maximum order quantity for each category to ensure the model doesn't favor appliances that occupy less space or have higher profit margins.

Constraint	Mathematical Formulation
Capacity <= 3,600 sqft	$30X_1 + 1.67X_2 + 4X_3 + 1.39X_4 + 2.33X_5 + 56X_6 + 30.38X_7 + 9.33X_8 <= 3,600$
Budget constraint	$350X_1 + 50X_2 + 15X_3 + 15X_4 + 120X_5 + 400X_6 + 200X_7 + 120X_8 <= 200,000$
Minimum order quantity for air conditioner	X1 >= 120
Minimum order quantity for coffee machine	X2 >= 240
Minimum order quantity for fans	X3 >= 600
Minimum order quantity lamps	X4 >= 480
Minimum order quantity microwave	X5 >= 180
Minimum order quantity refrigerator	X6 >= 96

Minimum order quantity washer and dryer	X7 >= 144
Minimum order quantity water heater	X8 >= 108
Maximum order quantity for air conditioner	X1<= 947
Maximum order quantity for coffee machine	X2<=7200
Maximum order quantity for fans	X3<=2769
Maximum order quantity for lamps	X4<=12000
Maximum order quantity for microwave	X5<=2769
Maximum order quantity for refrigerator	X6<=450
Maximum order quantity for washer and dryer	X7<=735
Maximum order quantity water heater	X8<=1565
Nonnegativity:	X1, X2, X3, X4, X5, X6, X7, X8 >= 0 and Integer

Results and Analysis

Based on the Integer Linear programming model formulation we have developed a spreadsheet model and applied Excel Solver to determine optimal order quantity for appliances. The optimal product mix is 120 Air conditioner units, 540 coffee machines, 600 fans, 480 lamps, 180 Microwaves, 96 Refrigerators, 144 washers and dryers and 108 water heaters with total profit of $152,040.

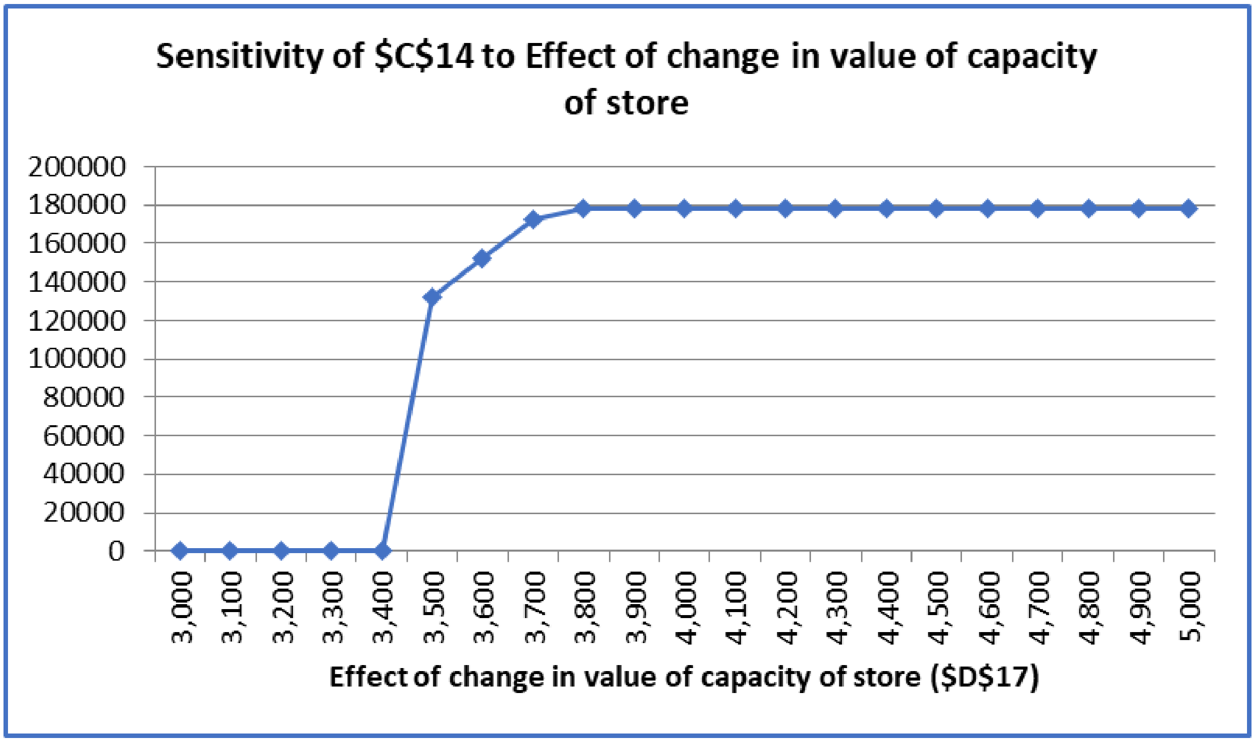
Model formulation

Decisions		Order quantity	Profit Per Unit	Cost per Unit	Area Per Unit	Sales Quantity
Air Conditioner	X1	120	150.0	350.0	3.8	100.0
Coffee machine	X2	540	100.0	50.0	0.5	200.0
Fans	X3	600	15.0	15.0	1.3	500.0
Lamps	X4	480	15.0	15.0	0.3	400.0
Microwave	X5	180	80.0	120.0	1.3	150.0
Refrigerators	X6	96	200.0	400.0	8.0	80.0
Washers and dryers	X7	144	150.0	200.0	4.9	120.0
Water heaters	X8	108	80.0	120.0	2.3	90.0
	Total	2268.0				
Objective Function		152040.00				
Constraints	*LHS*		*RHS*			
Capacity <= 3,600 sq ft	3600	<=	3,600			
Budget Constraint	186960	<=	200000			
Minimum order quantity for Air conditioner	120	>=	120			
Minimum order quantity for Coffee machine	540	>=	240			
Minimum order quantity for Fans	600	>=	600			
Minimum order quantity for Lamps	480	>=	480			
Minimum order quantity for Microwave	180	>=	180			
Minimum order quantity for Refrigerator	96	>=	96			
Minimum order quantity for Washer and Dryer	144	>=	144			
Minimum order quantity for Water heater	108	>=	108			
Maximum order quantity for Air conditioner	120	<=	947			
Maximum order quantity for Coffee machine	540	<=	7200			
Maximum order quantity for Fans	600	<=	2769			
Maximum order quantity for Lamps	480	<=	12000			
Maximum order quantity for Microwave	180	<=	2769			
Maximum order quantity for Refrigerator	96	<=	450			
Maximum order quantity for Washer and Dryer	144	<=	735			
Maximum order quantity Water heater	108	<=	1565			

The capacity constraint and minimum order quantity constraint of each appliance are obtained as the binding constraints after solving the model. This shows the maximum utilization of resources. The maximum order quantity is not obtained as a binding constraint due to the restriction in the capacity of the warehouse and budget.

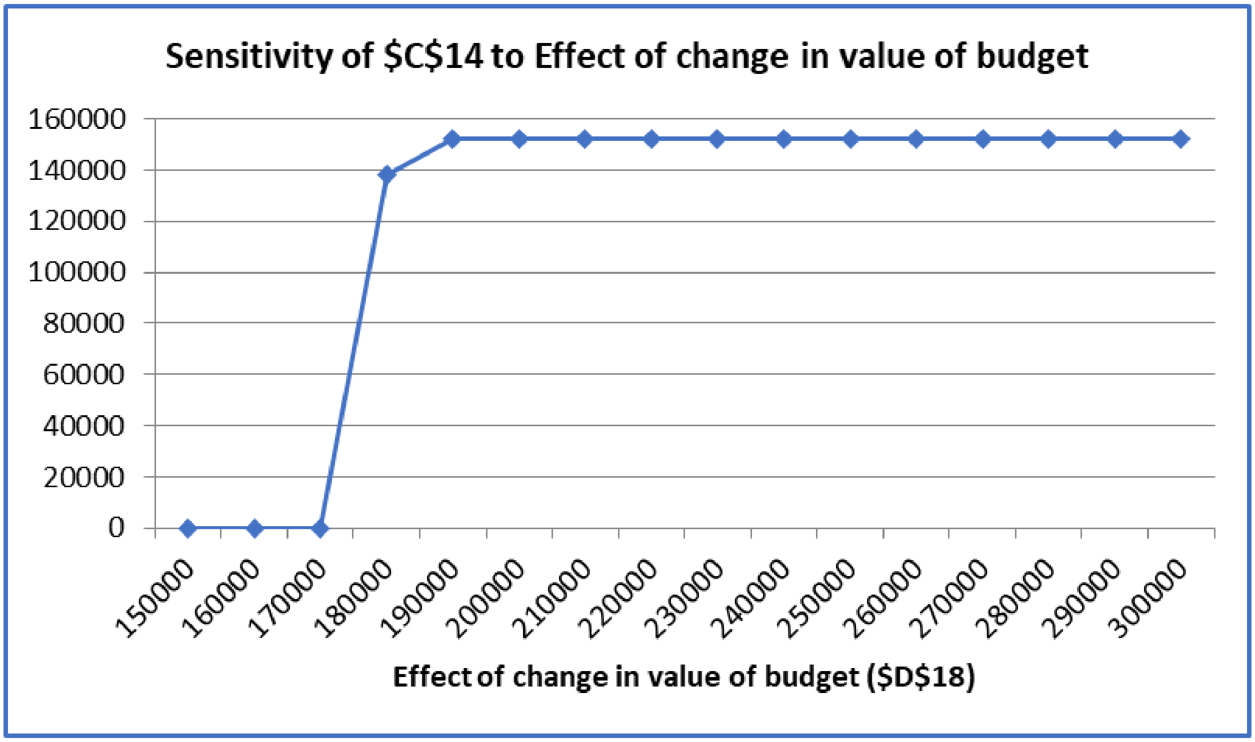
Considering the constraints of the model, we have performed one-way and two-way sensitivity analysis on the model. Using one-way sensitivity analysis for the RHS values of the capacity constraint, we investigate the effect on the total profit by changing the values of capacity.

The following figure shows the one-way sensitivity analysis for RHS of capacity constraint which is 3,600 sqft. C14 in the below figure represents the objective function in the spreadsheet model. X-axis shows capacity, Y-axis shows profit.



The analysis was conducted on the warehouse capacities from 3000 sqft to 5000 sqft with 100 sq ft increments. The analysis shows that the company can not have any profit (infeasible) for variations in warehouse capacities from 3000 sqft to 3400 sqft. From 3400 sqft we can see that the profit is sensitive to the variation of change in store capacity, which leads to a maximum profit of $180,000 at 3800 sqft past which again the profit stagnates (insensitive). The profit stagnation past 3800 sqft is due to the budget constraint ($200,000) as shown in the model formulation.

The following figure shows the one-way sensitivity analysis for RHS of budget constraint which is $200,000. C14 in the figure below represents the objective function in the spreadsheet model. X-axis shows budget, Y-axis shows profit.



The analysis was conducted on the budget limits from $150,000 to $300,000 with $10,000 increments. The analysis shows that the company can not have any profit (infeasible) for variations in budget between $150,000 and $170,000. From $170,000 we can see that the profit increases with increase in budget, which leads to a maximum profit of $150,000 at $190,000 budget, past which again the profit stagnates (insensitive). The profit stagnation is due the capacity constraint (3,600 sqft.) given in model formulation.

Therefore we can conclude that, based on the capacity, budget and maximum/minimum order quantity constraints, the company must order the model-suggested number of appliances to achieve the optimal profit of $152,040 for next year.

The following figure shows the two-way sensitivity analysis for RHS value of Capacity (along the side) and budget constraints (over the top). The capacity starts at 3000 sq ft and increases by 100 sqft, while the budget starts at $150,000 with increments of $10,000.

Capacity (cell D17) values along side, Budget (cell D18) values along top, output cell in corner

C14	150000	160000	170000	180000	190000	200000	210000	220000	230000	240000	250000	260000	270000	280000	290000	300000
3,000	Not feasit	Not feasit	Not feasit	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl
3,100	Not feasit	Not feasit	Not feasit	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl
3,200	Not feasit	Not feasit	Not feasit	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl
3,300	Not feasit	Not feasit	Not feasit	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl
3,400	Not feasit	Not feasit	Not feasit	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl	Not feasibl
3,500	Not feasit	Not feasit	Not feasit	132040.00	132040.00	132040.00	132040.00	132040.00	132040.00	132040.00	132040.00	132040.00	132040.00	132040.00	132040.00	132040.00
3,600	Not feasit	Not feasit	Not feasit	138070.00	152040.00	152040.00	152040.00	152040.00	152040.00	152040.00	152040.00	152040.00	152040.00	152040.00	152040.00	152040.00
3,700	Not feasit	Not feasit	Not feasit	138070.00	158070.00	172040.00	172040.00	172040.00	172040.00	172040.00	172040.00	172040.00	172040.00	172040.00	172040.00	172040.00
3,800	Not feasit	Not feasit	Not feasit	138070.00	158070.00	178070.00	192040.00	192040.00	192040.00	192040.00	192040.00	192040.00	192040.00	192040.00	192040.00	192040.00
3,900	Not feasit	Not feasit	Not feasit	138070.00	158070.00	178070.00	198070.00	212040.00	212040.00	212040.00	212040.00	212040.00	212040.00	212040.00	212040.00	212040.00
4,000	Not feasit	Not feasit	Not feasit	138070.00	158070.00	178070.00	198070.00	218070.00	232040.00	232040.00	232040.00	232040.00	232040.00	232040.00	232040.00	232040.00
4,100	Not feasit	Not feasit	Not feasit	138070.00	158070.00	178070.00	198070.00	218070.00	238070.00	252040.00	252040.00	252040.00	252040.00	252040.00	252040.00	252040.00
4,200	Not feasit	Not feasit	Not feasit	138070.00	158070.00	178070.00	198070.00	218070.00	238070.00	258070.00	272040.00	272040.00	272040.00	272040.00	272040.00	272040.00
4,300	Not feasit	Not feasit	Not feasit	138070.00	158070.00	178070.00	198070.00	218070.00	238070.00	258070.00	278070.00	292040.00	292040.00	292040.00	292040.00	292040.00
4,400	Not feasit	Not feasit	Not feasit	138070.00	158070.00	178070.00	198070.00	218070.00	238070.00	258070.00	278070.00	298070.00	312040.00	312040.00	312040.00	312040.00
4,500	Not feasit	Not feasit	Not feasit	138070.00	158070.00	178070.00	198070.00	218070.00	238070.00	258070.00	278070.00	298070.00	318070.00	332040.00	332040.00	332040.00
4,600	Not feasit	Not feasit	Not feasit	138070.00	158070.00	178070.00	198070.00	218070.00	238070.00	258070.00	278070.00	298070.00	318070.00	338070.00	352040.00	352040.00
4,700	Not feasit	Not feasit	Not feasit	138070.00	158070.00	178070.00	198070.00	218070.00	238070.00	258070.00	278070.00	298070.00	318070.00	338070.00	358070.00	372040.00
4,800	Not feasit	Not feasit	Not feasit	138070.00	158070.00	178070.00	198070.00	218070.00	238070.00	258070.00	278070.00	298070.00	318070.00	338070.00	358070.00	378070.00
4,900	Not feasit	Not feasit	Not feasit	138070.00	158070.00	178070.00	198070.00	218070.00	238070.00	258070.00	278070.00	298070.00	318070.00	338070.00	358070.00	378070.00
5,000	Not feasit	Not feasit	Not feasit	138070.00	158070.00	178070.00	198070.00	218070.00	238070.00	258070.00	278070.00	298070.00	318070.00	338070.00	358070.00	378070.00

As per the results obtained, there is no optimal solution if the capacity is below 3400 sqft. Similarly, there is no optimal solution if the budget is below $170,000.

Based on the two ways sensitivity outcomes, we can conclude that the company has the opportunity of maximizing the profit to reach $378,070 at the budget of $300,000 and warehouse capacity of 4,800 sq ft. Unlike in one-way sensitivity analysis where budget restricted the capacity and vice versa, we find from two-way sensitivity reports that without the budget or capacity restrictions the company can have a maximum profit of $378,070.

Conclusion

In conclusion, the project successfully demonstrated the effectiveness of using Excel Solver and Excel Solver Table add-in to build an optimization model for Home Needs. The model was able to achieve the goal of maximizing profit while considering various constraints such as budget, warehouse capacity, and minimum/maximum order quantities. By adopting this model, Home Needs can optimize their profit, ordering process and ensure that they sell as much inventory as they have considering the demand.

Additionally, sensitivity analyses were conducted to test the model under different scenarios, allowing Home Needs to make informed decisions in the face of changing circumstances.

Overall, this project provided valuable insights into the benefits of using optimization models in the retail industry. The use of data-driven decision-making can help companies like Home Needs to maximize profits. The findings of this project can be used as a basis for future research into optimization models in the retail industry.

It is recommended to Home Needs that they increase the budget and their capacity to store appliances since these were the primary constraints that were restricting the model. If Home Needs can increase only one parameter at a time, in the case of budget, the ideal budget would be $190,000 for procuring appliances. Increasing only the budget by any more than $190,000 will not have a significant impact on the profit because they will be limited by space. Likewise, if they can increase only space for storage, it is recommended that they increase the warehouse capacity to 3,800 sqft. Any more than that, the extra space cannot be utilized because they will be constrained by budget.

However, if Home Needs has the capacity to increase both budget and warehouse storage space at the same time, it is recommended that they increase their budget to $300,000 and warehouse capacity to 4,800 sqft.

One of the limitations of this model is that the variations in demand are overlooked. In reality, demand for home appliances varies from season to season, and can be a function of price, economic situation and other such factors. For the sake of simplicity and as a starting point, this model uses a 20% increase in demand from previous year’s data. Despite the linearity of this model, the results of this model are a good starting point for Home Needs.

Appendix

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