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Robust Optimization for Maximizing Customer Equity under Uncertainty: The Impact of Discounts

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ABSTRACT
The allocation of marketing budgets has always been one of the main issues in marketing as well as budgeting. In fact, executives are looking how to divide marketing budgets between customer acquisition and retention activities, such that the profit created by the customer is maximized. To do this, we require a mathematical modeling. Unfortunately, any model which is not consider uncertainty may arise questions in its applicability. Here, we have proposed a robust optimization model to cope with the uncertainty in the model parameters. This research tries to provide a rigor model in allocating customer relationship budgets to customer acquisition and retention activities, taking into account the uncertainty in the estimation of uncertain parameters, in order to maximize the customer equity. In fact, taking into account the conditions of the real world, which is unstable in practice, and due to uncertainty in the estimation of some parameters, a robust optimization approach is proposed. By using Malvey's scenario-based approach, the budget allocation model is presented. The comparison of the results obtained from the use of deterministic and robust models shows that the solution of the robust model remains stable in all examined conditions. Also, in the comparison of all the examined scenarios, the robust optimal solution is better than the deterministic optimal solution. The findings of this research can be used by organizations to increase long-term profits, increase the rate of customer acquisition and retention, target marketing programs and ultimately increase market share.
Keywords: robust optimization, robust solution, customer equity, marketing budget.

1. Introduction

One of the most important goal of establishing an economic organization is to earn profit, whereby higher profit margins signify more favorable outcomes for the organization. Historically, enterprises have centered their efforts predominantly on product-oriented strategies. However, in light of the intensifying competitive landscape, organizations have undergone a transformative shift towards customer-centric methodologies. This shift involves identifying and ranking customer needs following building a lasting relationship model. [8] Therefore, organizations should particularly focus on two key aspects: (1) retention of customers and transforming them to loyal customers; (2) acquiring new valuable customer. Both of them together help companies to obtain lasting profit. But this lasting profit which is a type of investment, like any other investment, needs budget and financial resources. [16]

Therefore, investors demonstrate a readiness to allocate a proportion of their financial resources to marketing activities that target both customer retention and acquisition. As a result, one of the most important concerns for investors revolves around the allocation of this budget across various marketing activities, with the aim of maximizing the organization's profitability stemming from its customer base. [16]

Since the 1980s, the concept of relationship marketing has gradually garnered substantial acceptance within the marketing domain. Developing and maintaining long-term relationships with customers is the main idea of relationship marketing. Notably, one of the profound outcomes of relationship marketing lies in its significant influence on managerial decision-making processes. The relationship marketing paradigm advocates for the adoption of customer equity (CE) as a suitable metric for evaluating organizational performance. Accordingly, maximizing CE should be regarded as the principal and long-term objective of organizations [4]

Customer equity (CE) represents the aggregate of customer lifetime values (CLV) for a specific customer group, where customer lifetime value denotes the net present value of the prospective profits arising from a customer during their entire association with the organization [9] , [4]The present research is presented in order to solve the concern of investors in the optimal allocation of marketing budgets with

the aim of maximizing profit from customers. In this way, as mentioned in the case study, it is completely clear how the available budget of the organization should be divided between the activities of customer attraction and retention so that the profit of the organization from its customers is maximized. It should also be mentioned in order to make the problem more practical and closer to the real world. Some parameters of the problem, such as customer acquisition rate and customer retention rate, were designed as a possibility and with different scenarios. That each scenario has a different probability from other scenarios. For this reason and because the solutions to the problem are justified and optimized, the stable optimization model has been used to solve the problem. Robust modeling is one of the best problem solving methods in probabilistic mode, which guarantees justified and optimal solutions.

The primary objective of this research is to address the concerns regarding the optimal allocation of marketing budgets to maximize profits from customers. By clarifying the allocation between customer acquisition and retention activities, the study provides a clear model for optimizing the organization's profitability, as demonstrated in the case study. To enhance the practicality and real-world relevance of the investigation, certain parameters, such as customer acquisition rate and customer retention rate, have been formulated as uncertain parameters. To address the uncertainty inherent in the specified parameters, a scenario-based robust optimization model has been utilized.

The remainder of this research is organized as follows: Following this introduction, the proposed approach is presented. The proposed model is subsequently followed by a presentation of numerical results, an analysis thereof, and the concluding remarks.

2. The proposed deterministic model

The first model proposed to allocate marketing budgets with the objective of maximizing customer equity was introduced [8]. Subsequently, [9]also presented models with similar objectives.

To outline our proposed deterministic model, we present the sets, parameters, and decision variables as follows:

Indices and Sets

i Index for the number of classes for customer price

j Index for customer grade

Parameters

a Customer acquisition rate

r Customer retention rate

m Margin contribution per customer

a_0 Mnimum rate of acquisition

C_a Ceiling rate of acquisition

r_0 Minimum rate of retention

C_r Ceiling rate of acquisition

B Available budget

Decision variables

A_{ij} Budget assigned to acquisition activities

R_{ij} Budget assigned to retention activities

According to the defined sets, parameters, and decision variables, the proposed mathematical model is as follows:

$$Max \quad CE = \sum_{j=1}^{J}\sum_{i=1}^{I}(a_{ij}m - A_{ij} + a_{ij}(m - \frac{R_{ij}}{r_{ij}})\frac{r_{ij}{}^{2}}{1 + r_{ij}{}^{2}})$$

s.t.

$$(A_{ij} + \sum_i \sum_j + \alpha R_{ij}) \quad \leq B$$
$$Aij, Rij \geq 0 \quad \forall i, j$$

$$a_{ij} = a_{0,ij} + (C_{a,ij} - a_{0,ij}) \frac{A_{ij}^{b_1}}{k_{1,ij} + A_{ij}^{b_1}} \qquad \forall i, j$$

$$r_{ij} = r_{0,ij} + (C_{r,ij} - r_{0,ij}) \frac{R_{ij}^{b_1}}{k_{2,ij} + R_{ij}^{b_1}} \qquad \forall i, j$$

In the above relations, the values of b_1, b_2 and K_1, K_2 are positive constant values that must be determined. To determine the parameters in the aforementioned model, management needs to address the following questions:

1. What is the minimum acquisition rate? This value occurs when there is no budget for potential customers.
2. What is the maximum acquisition rate? This amount occurs when the amount of budget spent on Saturation value reached?

By answering the first question, the parameter a_0 can be determined, and by addressing the second question, the parameter C_a can be obtained. Similarly, to calculate the retention rate parameter, r_0, maximum retention rate, C_r, in the second relationship, a similar process can be applied. Once again, two additional points on the curves need to be determined to estimate the other two fixed parameters. Each equation requires the estimation of two additional parameters. To determine these fixed parameters accurately, it is necessary to ascertain two other points on the corresponding curves. In this context, [10] propose that the status of the previous period and one additional point can be determined through informed management judgment. By formulating two equations, it becomes possible to identify and establish the values of the two unknown parameters within each relationship.

3. The proposed robust model

The market landscapes are predominantly characterized by pervasive uncertainty [9]. As a result, forward-looking metrics, such as customer value equity, necessitate the incorporation of inherent uncertainty in their model parameters [16]. The presence of uncertainty renders conventional deterministic models inadequate for achieving optimal resource and budget allocation. Consequently, it becomes crucial for innovative marketing approaches to adeptly tackle and integrate these uncertain conditions into their strategies.

In order to overcome this uncertainty, several methods can be used. In this research, we have used a robust optimization approach. Robust optimization is a relatively new approach to optimization under uncertainty when the uncertainty does not have a stochastic background or information about the distribution is not available.

Soyester (1973) proposed the first robust optimization model. After that, several robust optimization approaches have been developed. However, Mulvey (1975) have proposed a scenario-based robust optimization which is appropriate for our problem. Scenario-based robust optimization is a decision-making approach that takes into account uncertainty in a system by considering multiple possible scenarios or outcomes. In this method, instead of assuming a single fixed value for uncertain parameters, a range of possible values or scenarios is considered. The optimization is then performed for each scenario, and the decision is made by considering the robustness of the solution across all scenarios.

To introduce the scenario-based robust model, we begin by adopting the notations introduced for our deterministic model. Furthermore, we will introduce the following new sets, parameters, and decision variables. By employing the scenario-based model, the resulting robust model is formulated as follows, incorporating the newly introduced notations.

Indices and Sets

s Index for number of scenarios

Parameters

p_{ijs} Profit margin in each scenario for each price class in each customer grade

α The weight assigned to the variance of the solution in Mallvey's scenario-based method

p_s the probability of scenario occurrence

F_s The value of deterministic objective function for scenario s

Decision Variables

d_{ijs} Discount rate in each scenario for each price class in each customer grade

$$Min \quad \sum_{s=1}^{n} p_s F_s + \alpha \sum_{s=1}^{n} p_s (F_s - \sum_{s=1}^{n} p_s F_s)^2$$

s.t.

$$p_{ijs} \geq d_{ijs} \quad \forall i, j, s$$
$$d_{ijs} \geq 0 \quad \forall i, j, s$$

In which n represents the number of scenarios and each scenario s denoted with the same index. The probability associated with each scenario is expressed as p_s.

4. Results and analysis

The presented model is examined using data collected from a case study. Data was collected from a prominent food industry company in Iran. In this study, the company employs a customer segmentation strategy that involves classifying customers into five distinct price classes and three grades. The classification within the price classes is determined by the level of discount, which, in turn, is based on the purchase volume. Similarly, customer grades are assigned based on the combined factors of purchase volume, frequency of purchases, and total monetary value of purchases. Within each price class and grade, specific values for discounts and corresponding profit amounts are defined.

First, the presented deterministic model was solved with GAMS software, the results of which are as follows. In table number 8, the answer to the variables, which is the discount percentage in each price class and customer grade, is given, and in table number 9, the value of the objective function can be seen according to the answer to the variables.

Table 1. The results of the deterministic model

		customer class		
		1	2	3
customer grade	1	5.70%	5.40%	4.40%
	2	7.60%	6.70%	6.50%
	3	10.30%	9.40%	8.60%

	4	13.40%	12.40%	11.20%
	5	17.10%	15.30%	14.60%
Objective function		560.9		

In scenario-based robust optimization, it is essential to generate a sufficient number of scenarios, each of which requires examination to assess the results. To determine the appropriate number of scenarios, the uncertain model is analyzed for different values of n, specifically n = 1, 2, 10, 20, 50, and 100. The results indicate that a significant variation in the objective function values is observed when the number of scenarios reaches 50. However, employing more than 50 scenarios appears to be ineffective. Consequently, we set the number of scenarios, n, as 50, and herein, we present the results based on these 50 scenarios.

As depicted in the Table, the results exhibit significantly promising outcomes in the robust model when compared to the deterministic model.

scenario	Zd	Zr	improvement
1	387	616	59.17%
2	365	581	59.18%
3	357	532	49.02%
4	345	518	50.14%
5	388	610	57.22%
6	338	534	57.99%
7	353	552	56.37%
8	384	597	55.47%
Average	**365**	**568**	**55.57%**

Table 2 presents the results of the scenario-based robust optimization, comparing the objective function values (Zd) obtained from the deterministic model with the objective function values (Zr) from the robust model. The percentage improvement (improvement) is calculated based on the comparison. The outcomes demonstrate that the robust model consistently outperforms the deterministic model, with an average improvement of 55.57%.

Overall, the results showcase the efficacy of the scenario-based robust optimization approach in achieving better outcomes compared to the deterministic model, thereby demonstrating its potential for optimizing marketing strategies in the food industry company.

5. Conclusion

This research aims to achieve optimal customer communication budget allocation between customer attraction and retention activities while considering uncertainty in parameter estimation using an optimization approach. The ultimate goal is to maximize the customer's unique value, a critical aspect for organizations seeking long-term profit optimization, which can be achieved through the calculation of customer equity (CE).

In the proposed model, certain parameters are subject to uncertainty due to errors in their estimation, primarily those obtained from management judgments, including profit amount of each customer, interest rate, and customer retention rate. To address this uncertainty, robust optimization, a novel

approach under conditions of uncertainty, is employed to devise a solution that remains robust against variations in input data.

The research formulates the robust optimization model for budget allocation in customer communication based on Malloy's scenario-based approach. It is well-recognized that the robust model yields stable results across all conditions, ensuring the reliability and usability of the solution. In contrast, the deterministic model may generate unjustified and unreliable solutions under certain scenarios. Therefore, the robust model provides more reliable insights for managers and decision-makers, making it a valuable tool for optimizing customer communication budgets in organizations.

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