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RESEARCH PAPER

Revenue Sharing Contracts in Coalition Loyalty Reward Supply Chain Planning: A Stochastic Programming Approach

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ABSTRACT

A coalition loyalty program (CLP) is a strategic marketing initiative in which multiple companies form a partnership to offer a unified loyalty program to customers. By pooling their resources, these companies can offer customers a more attractive and comprehensive loyalty program than they could individually. This can lead to increased customer retention, higher spending per customer, and improved overall profitability. However, implementing a CLP requires careful planning and coordination between the participating companies. One key challenge is determining the coordination mechanism for reward distribution and revenue sharing among the partners. Revenue-sharing contracts (RSCs) are one possible mechanism that can be used to ensure that each partner receives a fair share of the revenue generated by the CLP.In this study, we investigated the role of RSCs in CLP supply chain planning, taking into account customer satisfaction and demand uncertainty. We used a two-stage stochastic programming approach to optimize decision-making and profitability for the host firm of the supply chain, comparing RSCs to the more common wholesale price contract (WPC).Our computational experiments showed that RSCs can be an effective incentive to increase the host firm's profit and reduce its cost. By offering revenue sharing to its partners, the host firm can encourage them to participate in the CLP and contribute to its success. This can lead to increased customer participation, higher revenue, and improved overall profitability for all partners.Overall, our study provides new insights into the management of CLPs and can be useful for business decision makers who are considering implementing or optimizing a coalition loyalty program.

KEYWORDS: *Loyalty program; Supply chain; Reward; Uncertainty; Stochastic programming; Points.*

1. Introduction

Nowadays, the competitive nature of markets involves companies' making more efforts to retain their customers because the customer acquisition cost is much higher than the customer retention cost. Loyal customers show less sensitivity to price changes and are more inclined to talk positively about that brand with their friends and family [21].

Loyalty reward program (LRP) is a program used by businesses to reward customers for their repeat purchases. It was originally developed as a marketing strategy to increase customer loyalty and consequently the company's long-term profitability. In the existing literature, LRPs are also known as loyalty programs (LPs), reward programs, "frequent seller" programs, or "frequent flyer programs." "Loyalty" and "reward" are the main concepts of these programs. "Loyalty" is the main goal of LRPs and "reward" is the main tool to achieve it [15].

Based on the relationships in LRPs, the host is a business entity that sets up or owns the program. Partners are business entities that join the program to provide point redemption and/or accumulation [25]. Depending on the organizational structure and relationships between the LRP host and LRP partners, there are three types of loyalty programs (LPs). In the type I structure, an LRP is completely and exclusively owned by the LRP host. In fact,

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the LRP host is the only sponsor that makes the LRP members capable of point redemption and/or accumulation. Type II and III structures that have developed in recent years have become more popular in large-scale LRPs. In type II structures, LRPs follow the same ownership and management structure as type I models, but they have multiple partners/sponsors for point redemption and/or accumulation. Type II LRPs are known as multi-sponsor programs or CLPs. An example is a structure where the LRP and related services are the core business of the host firm (e.g., Aeroplan, AirMiles). In contrast to type I and II structural models, the type III model represents a structure in which the LRP belongs to no firm (i.e. no individual host) and is formed when a number of companies join to develop a joint program known in the literature as the joint LRP program or cross-company program [25].

Unlike other types of LPs, a CLP is owned and managed completely by a "host" company that manages the program as a business entity independent of any business partner and develops customer loyalty around the program itself and its related reward system rather than around a product or service of a business partner [6]. Members who join CLPs enjoy a wide range of benefits. They get more opportunities to accumulate points through interactions with various business partners. This enables them to earn points (currency) much faster and spend their points with greater choices than other LPs to receive rewards. Among these, one of the most important issues facing the CLP host firms is the regulation of supply contracts, which will control the relationship between the host and each of its business partners as members of a supply chain. In cases where the host firm wants to establish a simple relationship with partners, a wholesale price contract (WPC) is more suitable (as shown by [7]. However, in cases where the host firm wants to have a closer relationship with the program partners, other types of contracts may be more suitable to manage the relationship between them. For example, the host and the point accumulation business partner can work together under an RSC. Considering a revenue-sharing coordination mechanism may allow the host to have more flexibility in the point accumulation management. It should be noted that the use of RSCs requires more efforts and management costs than that of WPCs.

Therefore, it is interesting to investigate how revenue-sharing (RS) policies can affect the decisions and profits of channel members. In relation to coalition loyalty reward supply chain planning, there has been little research attention towards the RS coordination mechanism considering customer satisfaction and demand uncertainty simultaneously. To fill this research gap, this study considers a supply chain, where the host sells points to its business partners under uncertain demand conditions and with the possibility of choosing a WPC or RSC. The innovations of this research are:

In short, this study will answer the following questions:

1- How is it possible to mathematically formulate the reward supply planning problem (RSPP) and arrive at good solutions for large-scale problems?
2- How does the type of RSC, compared with the WPC, affect the decisions of the supply chain and the profitability of the host?

Our findings provide new managerial insights that can prove helpful to business managers in this area. The rest of the article is organized as follows: first, previous studies on two related fields, namely LP and reward supply chain, and RSC in the supply chain, will be reviewed. The definition of the problem, hypothesis statement, problem description and model formulation will be provided in the third section. The solution methodology will be presented in the fourth section. It will start with a short introduction to stochastic linear programming and will then propose a suitable solution for solving the model. The numerical studies conducted through computer simulation, and the computational results will be presented and analyzed in the fifth section. Finally, the sixth section will highlight the main findings and management concepts and discuss future research orientation.

2. Literature Review

The literature is presented separately in two parts of the LP and supply chain of rewards, and RSC in the supply chain.

2.1. LP and supply chain of rewards

Increasing attention to customer relations in marketing can lead to the adoption of customer-based measures for the success of organizations and companies. LRPs have been widely used in almost every industry, especially in the consumer goods and service industries over the past three decades. The purpose of LRP is to attract customers and develop and maintain long-term relationships with customers [22], [12], [20]. Previous studies on LPs have addressed this issue from different perspectives, including marketing, management and economics.

[10] conducted a study to determine whether rewards match the efforts of LP members. They found that, on average, the price of points is higher than the market price, which is not good for the sustainability of LPs. [16]. investigated the customer loyalty cascade and its impact on profitability in financial services. They analyzed the loyalty development process and examined how customer loyalty affects profitability (positively). [35], investigated the reward points, profit sharing, and valuable coordination mechanism in the O20 era. They found that the financial support of the manufacturer would effectively alleviate the O2O competition and help improve the performances of all supply chain players. [9] investigated the liabilities and the point value in the LP. They found that LPs can act as barriers to uncertainty. [34] investigated the relationship between CLPs and the loyalty level. They found that customer satisfaction partially mediates the relationship between product fit and customer loyalty.

Most of the recent studies on CLP have focused on customer relationships with business partners from a marketing perspective and little research has dealt with this issue considering operational decisions. This has caused LP managers to use their experiences and observations rather than analysis-based methods to deal with the challenges posed in LP operations, such as income or cost optimization, reward supply planning, prediction of the point demand and redemption, etc. However, due to the growing size and complexity of LPs, it is impossible for LP managers to make appropriate operational decisions without the use of any analytical approach. Among modeling-based studies, [7] presented a stochastic linear modeling method and solution approach for the RSPP in LRPs. They formulated this problem as a two-stage stochastic linear program and developed a new sampling-based heuristic stochastic approach to solve it. [4] studied the RSPP considering the cooperative advertisement of the host firm. [14] designed competitive LPs and proposed a stochastic game theory model to choose the reward structure. [5] presented option contracts for the CLPs reward provision planning problem considering the budgeting limitation of the host firm. [1] analyzed the game theory of whether competing companies should offer "buy n times, get one free" LPs or not. They found that offering LPs is a superior strategy when customers highly value rewards rather than time.

In addition, several studies in the literature of LPs have recently addressed some specific issues in LRP operations. [23] discussed the advantages and limitations of advertising sales through the point sharing policy. They proposed a target rebate contract to coordinate a pair of retailers. They found that this contract may increase the profit of both retailers and divide it between the retailers, but the cost spillover phenomenon may be a bottleneck for maximizing overall profit. [13], studied the universal point scheme with multiple retailers and a platform that implements the points within a channel. Their study found that retailers are willing to set the lowest score conversion ratio in the marginal cost sharing mode compared to the decentralized and centralized control modes. [27] investigate the optimal design of coalition reward programs and their impact on customer loyalty and firm profit. The findings of this research can help businesses in designing optimal coalition reward programs to increase customer loyalty and firm profit. [32] examine the impact of coalition reward programs on customer behavior and store profits. The authors use a model to analyze the value of shared reward points among partner stores and how it affects customer behavior. They find that popularity affinity is the main determinant of cross-reward effects and that devaluing reward points can lead to larger financial losses for the most popular stores. The study provides insights into the effectiveness of coalition reward programs.

2.2. RSC in supply chain

Coordination of the supply chain to align the policies of the chain members and use the maximum possible profit for the supply chain has been the focus of many studies in the last decade. To achieve coordination, it is possible to use various mechanisms, including contracts. In general, coordination contracts are used in the supply chain when a variable at one level affects the profit of other members [24]. These contracts are used to coordinate the decisions of the supply chain members and optimize the decisions based on the total profit of the supply chain. Coordinating contracts pursue two main goals:

1. Proportionate distribution of the total expected profit of the chain among the members, as a centralized chain
2. Proportionate distribution of risk among the chain members

In RSC, the supplier sets a wholesale price for the retailer, but another parameter includes a fixed percentage of the chain's sales revenue, which is determined by the retailer. An RSC can play an important role in coordinating the distribution of benefits between upstream and downstream members of a supply chain and improving its overall performance. A main assumption in the application of RSC is the ability of the members (especially the suppliers) to monitor the income of sales, especially when part of the chain's income comes from the surplus sales scrapping (scrap income). This limitation has been removed in businesses such as video film rental, CD production industry, editing and newspaper services and sports leagues [19]. RSCs have the following characteristics:

- The supplier offers the retailer a lower price provided that the retailer shares a part of his/her income with the supplier.
- This type of contract leads to the cooperation of two members to determine the best ordering quantity.
- In this contract, the supplier receives money from two sources (direct sales, and a percentage of the income).

[3] investigated RSCs and found that these types of contracts are generally very attractive and increase integration in the supply chain. [18] modeled a supply chain with an RSC under uncertainty conditions. They found that the revenue-sharing rate will be higher for the supplier in the supply chain cooperation model under demand and supply uncertainty if the wholesale price remains the same. However, the wholesale price will be higher if the revenue-sharing ratio remains the same for the supplier.

[26] investigated the supply chain coordination using profit-dependent RSCs. They sought to understand why RSCs are (or are not) preferred over profit-independent contracts. They found that supply chains can be fully coordinated using both types of RSCs. [28] discussed supply chain coordination under an RSC with corporate social responsibility and partial demand information. [17] developed an RSC for reverse supply chain coordination under conditions of stochastic quality of returned products and uncertain remanufacturing capacity. [37] explored information exchange and sharing in a two-level supply chain with an RSC. [30] determined manufacturers' capacity procurement decisions through a commitment-based model with penalty and revenue-sharing.

2.3. Research gap and innovation

Despite the widespread use of CLPs, there are still many operational issues that need to be addressed in their management. One key challenge is designing effective contracts for coordination between the LP provider and its partners, taking into account factors such as demand uncertainty and customer satisfaction. In our study, we aimed to address this challenge by evaluating the effectiveness of different coordination contracts (WPC and RSC) on channel coordination performance. Specifically, we used a two-stage stochastic programming approach based on the sample average approximation (SAA) method to optimize decision-making and profitability for the host firm of the supply chain. Our approach allowed us to simultaneously consider the impact of customer satisfaction and demand uncertainty on LP performance, which is an important contribution to the existing literature. Additionally, our study is the first to evaluate the effectiveness of both WPC and RSC contracts on channel coordination performance using an operational stochastic programming approach. Overall, our study provides valuable insights into the management of CLPs and can be useful for business decision makers who are looking to implement or optimize a coalition loyalty program.

This study is based on [7] analytical framework, but they are different from several aspects. First, based on the arguments deployed in the literature review that LPs increase customer satisfaction and have a significant impact on customer retention, and considering the importance of this issue, the penalty cost of reducing customer satisfaction in the face of a lack of rewards and consequently the customers' reduced loyalty have been considered one of the goals of the host firm. Second, the possibility of choosing the type of contract is considered for coordination between the host and the accumulation partners. Accordingly, accumulation partners can choose an RSC instead of a WPC. Due to demand uncertainty, a two-stage stochastic programming approach is considered for the solution considering the discrete distribution of the demand, and the goal is to determine the optimal ordering quantity of rewards considering the maximization of the profit from the CLP by the host firm. In general, the innovative features of this study are described as follows:

1. Our study examines the coordination mechanism of revenue-sharing contracts in reward supply chain decisions of CLPs, which is an important but underexplored area of research.
2. We propose a novel mathematical model for revenue-sharing contracts that takes into account demand uncertainty, which is an important consideration in CLP management.
3. To solve our optimization problem, we use the sample average approximation (SAA)

method, which is a computationally efficient approach for handling stochastic programming problems.

4. We consider the cost of reduced customer satisfaction in the reward supply chain of CLPs, which is an important factor that can impact the success of the program.
5. By evaluating the impact of revenue-sharing contracts on the performance of the supply chain, we provide valuable insights into the effectiveness of different coordination mechanisms for CLPs.
6. Overall, our study provides important managerial insights into the management of CLPs, which can help businesses make more informed decisions about implementing and optimizing their loyalty programs.

3. Definition of the Problem

CLP basically refers to a program where reputable and well-known brands come together under a general group. Different people join it and start buying and collecting points and receiving discounts and rewards. In this way, the brands participating in this program will also earn a lot of income. The use of this concept was first proposed in the LP of one of the Canadian airlines called Air Miles in 1992. Then, an English company used the idea of this plan to launch a program called Nectar in 2002, which is still considered one of the most successful loyalty coalitions in the world. In modeling the problem, CLP is considered a rewards points supply chain (consisting of two parallel supply chains of point redemption and/or accumulation) that offers non-storable goods to customers (as a reward) and the host firm operates separately in the roles of supplier and buyer with each supply chain of business partners. On this basis, Fig. 1 shows the conceptual model of the supply chain of loyalty points. Customers who are members of the LP receive points for purchasing products or services from the network of existing partners, which they can redeem and convert into rewards based on a predetermined reward structure.

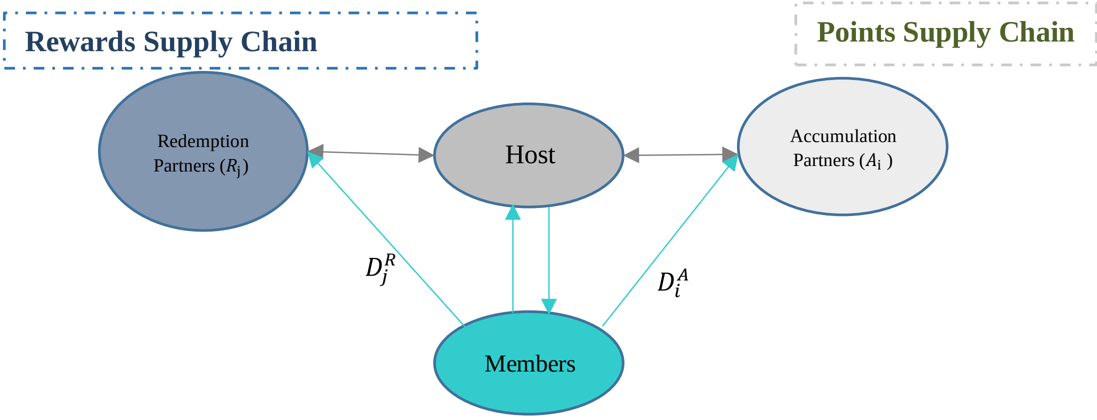


Fig. 1. A conceptual model of the CLP supply chain

According to [7], in this conceptual model, the host firm cooperates with point redemption partners (providers of rewards to LP members) ($R_j\ j = 1 \dots J$), point accumulation partners (providers of points to LP members) (A_i , $i =$ 1,…,I) and customers who are members of the LP (those who collect points and then redeem them to receive rewards). In the LP supply chain, points are distributed as common currency among the entities of this program (host, partners and customers).

Notations:

Indices

A_{1i}	Accumulation partners, who allow members to collect points through their purchasing of products or services, and choose a wholesale price contract, $1i = 1 \dots I$
A_{2i}	Accumulation partners, who allow members to collect points through their purchasing of products or services, and choose a revenue-sharing contract, $2i = 1\ \dots\ I$
H	Host, who runs an LP as a profit center

R_j	redemption partners, who offer rewards to members $j = 1\ 2\ \ldots\ J$

Parameters

w_{1i}^A	Wholesale price per unit of points that host H charges to accumulation partner A_{1i}
w'^A_{1i}	Price per unit of points that host H charges to accumulation partner A_{1i} when accumulation demand is over ordering quantity. $D_{1i}^A > q_{1i}^A$
w_{2i}^A	Revenue-sharing in terms of the price per unit of points that host H charges partner A_{2i}
w'^A_{2i}	Extra revenue-sharing in terms of the price per unit of points that host H charges partner A_{2i} when the actual revenue increase is higher than that to which H has committed.
S_{2i}^A	Penalty per unit of points that host H pays to partner A_{2i} when the actual revenue increase is lower than that to which H has committed.
q_{1i}^A	Accumulation partner A_{1i} 's ordering quantity of points.
q_{2i}^A	Accumulation partner A_{2i} 's ordering quantity of points.
D_{1i}^A	Members' accumulation demand towards accumulation partner A_{1i}
D_{2i}^A	Members' accumulation demand towards accumulation partner A_{2i}
D_j^R	Members' redemption demand towards redemption partner R_j
w_j^R	Wholesale unit price of rewards that redemption partner R_j charges to host
p_j^R	Per unit point value of rewards offered by redemption partnerR_j
v_j^R	Cost of reducing customer satisfaction per unit shortage of redemption partner R_j reward.
l_0	Liability in points at the beginning of the planning horizon.
l	Target liability in points at the end of the planning horizon.
L_{UB}	Upper bound of liability control limits for the planning horizon.
Q_j^R	Redemption partner R_j capacity limitation on offering rewards.
W^R	Host H's budget limitation on purchasing rewards

Decision variables

q_j^R	Host H's ordering quantity of rewards from LRP partner R_j

Assumptions of the model:

As in [7], [6] Cao, we consider the following modelling assumptions**:**

1- The relationship between the host and partners is based on contracts.
2- The redemption partners have the limitation of providing the capacity of the proposed rewards.
3- The host has no capacity limit in issuing points.
4- The point accumulation demand is always fulfilled.
5- Point redemption and/or accumulation demands are not determined with certainty, but they have a certain probability distribution and the two demands are independent of the price.
6- Customers' point accumulation demands from each of the accumulation partners are independent of each other.
7- Point redemption demands from each of the redemption partners are independent of each other.
8- Customers' point accumulation demands are independent of each other.
9- The ordering quantity of the accumulation partners' points is equal to the average quantity of the customers' point accumulation demands)
10- WPC is used as a legal mechanism

between the host and the partners for point accumulation and redemption.

11- RSC is used as a legal mechanism between the host and some point accumulation partners.

12- Point accumulation partners have the right to choose the type of contract (revenue-sharing, wholesale) with the host.

13- The considered model is based on the single-period newsvendor model.

3.1. Value creation process in the points-rewards supply chain of the CLP:

Under the CLP business model [7] proposed the model in two different accumulation and redemption sides.

Value creation during point accumulation

When a customer buys a product or service from an accumulation partner, the acquisition value for the customer is the points he/she gets by buying the product or service (in addition to the purchased product). The acquisition value for the point accumulation partner is the revenue coming from the sale of the service or product to the customer. It should be noted that the accumulation partner does not directly issue the customer's points, but he/she buys these points from the host firm (issuer of the points), thereby generating income for the host. In this article, it is assumed that accumulation partners have the right to choose the type of coordination mechanism with the host, and they can thus choose two types of WPC or RSC. As shown in Equation (1), the first and second terms represent the case where the accumulation partners ($\boldsymbol{A_{1I}}$) choose the WPC proposed by the host, so the host will sell the points at the wholesale price ww_{1i}^{A} to the point accumulation partner, based on which he/she determines the ordering quantity of his/her points (q_{1i}^{A}). The quantity of points demanded by the customer is unknown, but it follows a certain probability distribution. At the end of the planning period, if the customer's point demand is more than the ordering quantity of points ($D_{1i}^{A} > q_{1i}^{A}$), the host firm sells the required quantity of points to the accumulation partner at the price of w'^{A}_{1i}, in which case $w'^{A}_{1i} > w_{1i}^{A}$.

The third to fifth terms represent a case where the accumulation partners ($\boldsymbol{A_{2I}}$) choose the host-proposed RSC. In this contract, the host offers to the A_{2I} partner to order the quantity of points q_{2i}^{A} at the price w_{2i}^{A}) $w_{2i}^{A} < w_{1i}^{A}$. If the demand quantity of points is greater than their ordering quantity ($D_{2i}^{A} > q_{2i}^{A}$(), the actual revenue increase will be greater than the minimum committed quantity, and the additional revenue increase will be paid to the host. However, if the quantity of point demand is less than the ordering quantity of points ($D_{2i}^{A} < q_{2i}^{A}$), the actual $D_{2i}^{A} < q_{2i}^{A}$ will be less than the minimum quantity that the host has committed and the host will pay a penalty fee of S_{2i}^{A} units to the A_{2I} partner. The profit function of the host firm is defined as follows:

$$\pi_{H(A)} = \left[\sum_{1i=1}^{I_1} (w_{1i}^{A} \times q_{1i}^{A} + w'^{A}_{1i} \times [D_{1i}^{A} - q_{1i}^{A}])\right] + \left[\sum_{2i=1}^{I_2} (w_{2i}^{A} \times q_{2i}^{A} + w'^{A}_{2i} \times [D_{2i}^{A} - q_{2i}^{A}]) - S_{2i}^{A} \times [q_{2i}^{A} - D_{2i}^{A}])\right] \quad (w'^{A}_{2i} > w_{2i}^{A} \;\; w'^{A}_{1i} > w_{1i}^{A}) \tag{1}$$

Value creation during point redemption:

When the customer wants to redeem his/her points to receive a reward, the host must purchase the reward from the redemption partners in order to be able to respond to the customer's point redemption demand, and in exchange for the reward, he/she gets a certain quantity of the customer's points. The acquisition value for the host is the difference between the value of the reward (the number of points required for the reward) and the amount that the host spends to buy the reward. The acquisition value for the redemption partner is the revenue from selling rewards to the host, and the customer acquisition value is the reward they receive for point redemption.

In the first and second terms of Equation (2), the redemption partner receives w_{j}^{R} from the host firm as a reward for redeeming each point. Based on that, the host firm must decide on the quantity of its reward order to the redemption partners (q_{j}^{R}) and the Rial value of each reward point provided by the redemption partner to the customer is considered equal top_{j}^{R}. It should be noted that the quantity of point redemption demand by the customer from the redemption partners is unknown, but it follows a certain probability distribution.

At the end of the planning period, if the customer's point redemption demand (receiving a reward) is more than the ordering quantity of rewards, the host will be short of rewards, which will lead to members' dissatisfaction with the LP. Customer satisfaction is a key element for any organization that wishes to increase customer loyalty and generate a better business outcome. The role of satisfaction in loyalty largely suggests that the former is a key determinant of the latter [11]. Therefore, considering the importance of this issue, v_j^R is determined as the cost of customer satisfaction reduction and, consequently the reduction of their loyalty for the host. Therefore, the profit function of the host firm is defined as follows:

$$\pi_{H(R)} = \sum_{j=1}^{J} \left(-w_j^R \times q_j^R + p_j^R \times min\{q_j^R . D_j^R\} - v_j^R \times \left[D_j^R - q_j^R\right]^+ \right) \tag{2}$$

3.2. Model description:

The host wants to know the **optimal ordering quantity of rewards** according to the ordering quantity of points agreed by the accumulation partners in the contract in order to have the maximum profitability considering the limits of the rewards capacity, the reward purchase budget and points liability control.

$$\Pi_H\left(q_j^R;\ D_j^R . D_i^A\right) = \max E\left[\pi_{H(A)} + \pi_{H(R)}\right] \tag{3}$$

$$= \max \left(\begin{array}{c} E\left(\left[\sum_{1i=1}^{I_1}(w_{1i}^A \times q_{1i}^A + {w'}_{1i}^A \times [D_{1i}^A - q_{1i}^A])\right] + \left[\begin{array}{c}\sum_{2i=1}^{I_2}(w_{2i}^A \times q_{2i}^A + {w'}_{2i}^A \times [D_{2i}^A - q_{2i}^A]) - \\ S_{2i}^A \times [q_{2i}^A - D_{2i}^A])\end{array}\right]\right) + \\ E\left[\sum_{j=1}^{J}(p_j^R \times min\{q_j^R . D_j^R\}) - (v_j^R \times \left[D_j^R - q_j^R\right])\right] - \sum_{j=1}^{J}(w_j^R \times q_j^R) \end{array} \right)$$

Subject to:

$$q_j^R \le Q_j^R \ . for\ j = 1. \dots . J \tag{4}$$

$$\sum_{j=1}^{J}(w_j^R \times q_j^R) \le W^R \tag{5}$$

$$\frac{l}{l_0} \le L_{UB} \ . where\ l = l_0 + \sum_{1i=1}^{I_1}(q_{1i}^A + \left[D_{1i}^A - q_{1i}^A\right] + \sum_{2i=1}^{I_2}(q_{2i}^A + \left[D_{2i}^A - q_{2i}^A\right]) - \sum_{j=1}^{J}(min\{q_j^R . D_j^R\}) \tag{6}$$

$$q_j^R \ge 0 \ . for\ j = 1. \dots . J \tag{7}$$

The objective function (3) shows the profitability of the host according to the exchange of points and rewards with its partners. Constraint (4) indicates that each of the point redemption partners has a capacity limitation in the quantity of rewards provided to the LP host. Constraint (5) indicates that the host's reward purchase budget is limited. Constraint (6) is related to the control of the points collected by customers, which are stored in their account. The host keeps these points as liability until they are redeemed by the members to receive rewards. Therefore, the balance of the total points at the end of a period (l) is equal to the available points (l_0) at the beginning of the period plus the total quantity of points collected by the members during the planning horizon, from which the total quantity of points that the members repurchase for rewards in the same planning horizon will then be deducted. Constraint (7) indicates that the decision variable is non-negative.

4. Solution

Due to the uncertainty of the point redemption and/or accumulation demands, the model proposed in this study is a stochastic programming model, so the stochastic programming optimization approach is used to solve the model and combine uncertainty in the decision-making process. Stochastic programming has been used in a wide range of research problems, including production planning, supply chain network design, and allocation problems, among others [36], [29], [33]. Most of the models proposed in these studies involve minimizing (or maximizing) the expectation resulting from the distribution of stochastic components. The advantage of using stochastic programming to deal with uncertainty is that it allows for the optimal solution to be obtained with respect to the variation of stochastic elements, which is stronger than the optimal solution of the corresponding certain problem in which the stochastic elements are replaced by mean values.

In our study, we used a two-stage stochastic linear programming with recourse (2SLPR) approach, which is a special type of stochastic linear programming. This approach allows us to classify the decision variables into two stages based on whether they are observed before or after the result of a random variable, which is an effective way to handle uncertainty in the decision-making process.

Problem-2SLPR is suitable for single-period stochastic decision models (for example, models based on the newsvendor model). Our model fulfills this feature. Therefore, it can be rewritten in 2SLPR form as follows.

$$\max \Pi_H = \max(\sum_{1i=1}^{I}(w_{1i}^A \times q_{1i}^A) + (\sum_{2i=1}^{I}(w_{2i}^A \times q_{2i}^A) + \sum_{j=1}^{J} p_j^R \times q_j^R - w_j^R \times q_j^R) + E_\xi[\mathrm{g}(x,\omega)] \tag{8}$$

S.T:

$$q_j^R \leq Q_j^R \ . for\ j = 1. \dots . J \tag{9}$$

$$\sum_{j=1}^{J}(w_j^R \times q_j^R) \leq W^R \tag{10}$$

$$q_j^R \geq 0\ . for\ j = 1. \dots . J \tag{11}$$

Where g (x, ω) is equal to the equation below:

$$\mathrm{g}(x,\omega) = g\left(q_J^R, D_{1i}^A, D_{2i}^A, D_J^R\right) = \tag{12}$$

$$\max\ \sum_{1i=1}^{I_1}(w'^A_{1i} \times I_{1i}^{A-}) + \sum_{2i=1}^{I_2}(w'^A_{2i} \times I_{2i}^{A-}) - \left(S_{2i}^A \times I_{2i}^{A+}\right) - (w_{2i}^A \times I_{2i}^{A+}) - (\sum_{j=1}^{J}(v_j^R \times I_j^{R-} + p_j^R \times I_j^{R+}))$$

S.T:

$$\frac{l}{l_0} \leq L_{UB}\ . where\ l = l_0 + \sum_{1i=1}^{I_1}(q_{1i}^A + I_{1i}^{A-}) + \sum_{2i=1}^{I_2}(q_{2i}^A + I_{2i}^{A-} - I_{2i}^{A+}) - \sum_{j=1}^{J}(q_j^R - I_j^{R+}) \tag{13}$$

$$I_{1i}^{A+} - I_{1i}^{A-} = q_{1i}^A - D_{1i}^A \quad 1i = 1. \dots . I_1 \tag{14}$$

$$I_{2i}^{A+} - I_{2i}^{A-} = q_{2i}^A - D_{2i}^A \quad 2i = 1. \dots . I_2 \tag{15}$$

$$I_j^{R+} - I_j^{R-} = q_j^R - D_j^R \quad j = 1. \dots . J \tag{16}$$

$$I_{2i}^{A+}, I_{2i}^{A-}\ I_{1i}^{A+}, I_{1i}^{A-}\ \ I_j^{R+}\ \ I_j^{R-} \geq 0 \quad 1i = 1. \dots . I_1 \quad j = 1. \dots . J\ \ 2i = 1. \dots . I_2 \tag{17}$$

In this model, $\omega = \{D_{1i}^A . D_{2i}^A . D_j^R\}$ represents stochastic vectors. The vector of the first-stage decision variables is $x = \{q_j^R\}$and the vector of the second-stage decision variables is $\mathrm{y}(\omega) = \{\mathrm{I}_{2i}^{A+} . \mathrm{I}_{2i}^{A-} . \mathrm{I}_{1i}^{A+} . \mathrm{I}_{1i}^{A-} . \mathrm{I}_j^{R+} . \mathrm{I}_j^{R-}\}$, where I_i^{A+} و $I_i^{A-} . I_j^{R+} . I_j^{R-}$ are the new decision variables defined in the second stage.

II_j^{R+}, I_{2i}^{A+} and I_{1i}^{A+} represent the values of $\left[q_j^R - D_j^R\right]^+$, $\left[q_{1i}^A - D_{1i}^A\right]^+$ and $\left[q_{2i}^A - D_{2i}^A\right]^+$, respectively and I_j^{R-}, I_{1i}^{A-} and I_{2i}^{A-} represent the values of $\left[D_{1i}^A - q_{1i}^A\right]^+$, $\left[D_j^R - q_j^R\right]^+$ and $\left[D_{2i}^A - q_{2i}^A\right]^+$, respectively. The values of the decision variables of the second stage depend on the demand variation.

$min\{q_j^R . D_j^R\}$ in the main model is replaced by $q_j^R - I_j^{R+}$ in the two-stage model. In the constraint of account balance, the points of $[D_{2i}^A - q_{2i}^A]^+$ and $[D_{1i}^A - q_{1i}^A]^+$ are replaced by I_{2i}^{A-} I_{1i}^{A-} in the constraint of the two-stage model.

Constraint (14) indicates the values of I_{1i}^{A+}, I_{1i}^{A-} so that if $D_{1i}^A \geq q_{1i}^A$, then $I_{1i}^{A-} = D_{1i}^A - q_{1i}^A$ and $I_{1i}^{A+} = 0$ and if $D_{1i}^A \leq q_{1i}^A$, then $I_{1i}^{A+} = D_{1i}^A - q_{1i}^A$ and $I_{1i}^{A-} = 0$.

Constraint (15) represents the values of $I_{2i}^{A+} . I_{2i}^{A-}$ so that if $D_{2i}^A \geq q_{2i}^A$ then q_{2i}^A -D_{2i}^A =I_{2i}^{A-} and = 0 I_{2i}^{A+}, and if $D_{2i}^A \leq q_{2i}^A$ then $I_{2i}^{A+} = q_{2i}^A$ -D_{2i}^A and I_{2i}^{A-} =0.

Constraint (16) represents the values of $I_j^{R+} . I_j^{R-}$ so that if $D_{1i}^A \geq q_{1i}^A$ then $I_j^{R-} = D_j^{AR} - q_j^R$ and $I_j^{R+} = 0$ and if $q_j^R \geq D_j^R$ then I_j^{R+} q_j^R $-D_j^R$ and $I_j^{R-} = 0$.

In general, it is not easy to solve a stochastic programming model due to the stochasticity in the model. The solutions are divided into two main categories:

(1) Exact methods including L-shaped method and regular decomposition approach

(2) Sampling-based heuristic solution approach. Techniques such as SAA or stochastic decomposition approach

An approximation approach based on the Sampling Average Approximation (SAA) scheme e.g., [31] was used to solve the model proposed in this study. SAA is a scenario-based method in which a number of scenarios are considered in each iteration and the obtained solutions are analyzed together each time the problem is solved. In this method, M times and N scenarios are selected from the problem, and then a two-stage optimization problem is solved with each N scenario. As a method based on Monte Carlo simulation for solving stochastic discrete optimization problems, the main idea of SAA is that the expected objective value of the stochastic problem can be approximated by the corresponding value of the sampling problem, which involves the following steps:

1- The problem is solved M times with N scenarios. The higher the M and N values, the higher the accuracy and cost, i.e. $[w_1^m . w_2^m .... w_N^m]^T$i

2- For each, m= [1,…,M], N problems are solved independently. x_m and π_m are the solution and the objective function value found for the problem, respectively.

3- The values of $\bar{\pi}_{N.M}$ and $\delta_{N.M}^2$ are calculated as follows.

$$\bar{\pi}_{N.M} = \frac{\sum_{m=1}^{M} \pi_m}{M}$$

$$\delta_{N.M}^2 = \frac{\sum_{m=1}^{M} (\pi_m - \bar{\pi}_{N.M})^2}{M(M-1)}$$

4- We need to find a reasonable solution to the original problem for the variables of the first stage. Now we choose the number N' where $N' \gg N$ and solve the problem with N' scenarios and M' times.

Let $\hat{x}_{\acute{N}}$ be the corresponding optimal solutions and. π' be the corresponding objective function value.

$$\bar{\pi}'_{N'.M'} = \frac{\sum_{m'=1}^{M'} \pi_{m'}}{M'}$$

$$\delta_{N'.M'}^2 = \frac{\sum_{m'=1}^{M'} (\pi_{m'} - \bar{\pi}'_{N',M'})^2}{M'(M'-1)}$$

5- Now we calculate the gap using the lower and upper bounds calculated for the value of each objective function

$$G_N^m(\hat{x}_{\acute{N}}) = \bar{\pi}_{N.M} - \bar{\pi}'_{N'.M'}$$

Then, we test the quality of the candidate solution by limiting the optimal gap between the estimated actual target value and the expected target value of the candidate solution using standard statistical methods.

5. Computational Results

The model of the problem was coded in GAMs 25.1.2 language and all numerical experiments were performed on an ASUS zenbook 13 notebook equipped with a 2.4 GHz processor. We conducted two main types of numerical experiments to evaluate the solvability and effectiveness of our proposed solution:

(1) Examining the quality of the solutions obtained using our stochastic programming model in comparison with the solutions obtained using deterministic models with mean values

(2) Examining the effects of using the RSC on profitability, liability ratio and budgeting costs in the model

Table 1 shows the values considered for the parameters of the problem. All problems were stochastically generated similar to the design described in [5]. By conducting these numerical experiments, we were able to provide valuable insights into the effectiveness of our proposed solution and the impact of different coordination mechanisms on the performance of the coalition loyalty program.

Tab. 1. Generation parameters.

parameter	Parameter range
number of accumulation partners	2-95
number of redemption partners	1-100
w_j^R	6
w_{1i}^A	[10-17]
w'^A_{1i}	$w_{1i}^A[1.5-2]$
w_{2i}^A	$0.8w_{1i}^A$
w'^A_{2i}	$w_{2i}^A[1.5-2]$
p_j^R	$w_j^R[2-10]$
v_j^R	7
l_0	50
S_{2i}^A	$0.6w_{2i}^A$
q_{1i}^A	[5-55]
q_{2i}^A	[5-55]
D_{1i}^A	Uniform distribution: [5-50]
D_{2i}^A	Uniform distribution: [5-50]
D_j^R	Uniform distribution: [5-50]
L_{UB}	2
Q_j^R	75
W^R	45000

To solve it, we created 10 problems, depending on the number of point redemption partners (j) and the number of point accumulation partners (1i, 2i), from small to large, the specifications of each of which are given in Table 2. N, M, ND, and NC represent the sample size, the number of sample repetitions, the number of decision variables, and the number of constraints, respectively. In the SAA method, N = 60 (sample size), M = 30 (number of sample repetitions) and (N=300) (sample size used to evaluate the true objective function value) were considered because based on the computation time and quality of the solution method, these parameters have been shown to provide a relatively good balance between solution quality and computation time (see [7]. Accordingly, the largest problem has 12,000 decision variables and 6,000 constraints.

Tab. 2. Generation senarios.

Problem Number	revenuesharing							NO-revenuesharing						
	(j)	(i1)	(i2)	Number of sample of demand realisations (N)	Number of sample replications (M)	Number of decision variables (ND)	Number of constraints (NC)	(j)	(i1)	(i2)	Number of sample of demand realisations (N)	Number of sample replications (M)	Number of decision variables (ND)	Number of constraints (NC)
1	1	1	1	60	30	120	60	1	2	0	60	30	120	60
2	3	2	3	60	30	360	180	3	5	0	60	30	360	180
3	10	5	5	60	30	1200	600	10	10	0	60	30	1200	600
4	20	5	10	60	30	2400	1200	20	15	0	60	30	2400	1200
5	25	15	15	60	30	3000	1500	25	30	0	60	30	3000	1500
6	40	20	20	60	30	4800	2400	40	40	0	60	30	4800	2400
7	60	25	30	60	30	7200	3600	60	55	0	60	30	7200	3600
8	65	30	40	60	30	7800	3900	65	70	0	60	30	7800	3900
9	80	30	50	60	30	9600	4800	80	80	0	60	30	9600	4800
10	100	45	50	60	30	12000	6000	100	95	0	60	30	12000	6000

5.1. Evaluation of the effectiveness of the proposed solution

The effectiveness of the proposed solution method is evaluated from the perspective of value of the stochastic solution (VSS). The quality of stochastic solutions seeks to examine whether the use of stochastic programming method is suitable and valuable. To evaluate the quality of stochastic solutions, the solution of the stochastic optimization model is often compared with the result of the deterministic optimization model, which includes the mean values of the parameters of the uncertain problem [8]. The difference between the expected values of the stochastic model and the corresponding mean value model are known as VSS [2]. If the value of VSS is greater than zero, the stochastic model is not worse than the deterministic model, indicating that the use of stochastic models is valuable. The higher the VSS value, the more suitable the stochastic models are compared to deterministic models. To calculate the VSS in the model, we replace the stochastic parameters of the point redemption and/or accumulation demands with the mean of each in the model (x^{MVP} and then solve the resulting deterministic model and calculate the value of the objective function.

$$VSS = \hat{\pi}(\bar{x}) - \hat{\pi}(x^{MVP})$$

Tables 3 report the solutions of the stochastic and mean-value solutions, with and without the RSC. The results given in Table 3 show that the value of the stochastic solution is greater than zero, indicating that the optimal values estimated from the objective function (profitability) for the solution based on the stochastic programming model with and without the RSC is more than the mean-based model. This shows the importance of using stochastic programming in the problem and it means that solving the problem by considering the uncertainty is valuable. This finding is consistent with previous research that has shown that RSCs can be an effective coordination mechanism for supply chain management. Overall, the results presented in Table 3 provide strong evidence for the effectiveness of our proposed solution method and the importance of considering uncertainty in the management of coalition loyalty reward supply chains.

Tab. 3. Evaluation of the proposed solution (Quality of stochastic vs. mean-value solutions)

Problem Number	revenuesharing			NO-revenuesharing		
	Stochastic model objective function	Mean value model objective function	VSS (%)	Stochastic model objective function	Mean value model objective function	VSS (%)
1	112218.179	112196.003	0.01976541	98920.429	97980.989	0.958798
2	111289.975	111258.969	0.027868315	110277.298	110214.737	0.056763
3	162537.698	162259.524	0.171437702	145759.883	145722.739	0.02549
4	140797.826	140024.672	0.552155552	130415.241	130131.757	0.217844
5	169575.314	169058.914	0.305455647	161606.518	160803.632	0.499296
6	166898.557	166813.11	0.051223192	160656.548	160310.167	0.216069
7	189896.867	188192.028	0.905903942	182565.63	180994.248	0.868194
8	211235.593	210982.317	0.12004608	208020.12	207515.881	0.242988
9	236905.307	236296.276	0.257740414	234976.868	234103.092	0.373244
10	264318.255	263165.959	0.437859062	262457.583	262388.767	0.026227

5.2. RSC vs. WPC

Table 4 presents the results related to the optimal decisions of the host firm for the model with RSCs and for the model based solely on WPCs. These results include "Host's Profitability", "Total Rewards", and "Use of Budget ". Host's profitability and total reward represent the host's maximum (approximate) profitability and optimal reward purchase quantities, respectively. Use of budget (%) represents the percentage of budget used for optimal reward values. Our findings revealed that RSCs generally perform better than WPCs when the LP host is faced with the uncertainty of demand. With an RSC, the host is likely to achieve higher profitability using a lower point redemption budget, because fewer total rewards are purchased. These results demonstrate that RSCs play an important role in mitigating the budget used for optimal quantity of rewards and have a relatively higher profit for the host than WPCs. Overall, the results presented in Table 4 provide strong evidence for the effectiveness of RSCs as a coordination mechanism in the management of coalition loyalty reward supply chains. By using RSCs, the host firm can achieve higher profitability and better manage the budget for reward purchases, which is important for the long-term sustainability of the coalition loyalty program.

Tab. 4. Summary results of ordering quantity of rewards, budget used and host profitability considering different contracts (revenue-sharing VS. no-revenue-sharing)

Problem Number	Host profitability		Budget used (%)		Total rewards(q_i^R)	
	revenuesharing	NO-revenuesharing	revenuesharing	NO-revenuesharing	revenuesharing	NO-revenuesharing
1	112218.179	98920.429	74.264	75.758	11.981	12.406
2	111689.975	110277.298	76.11	75.913	22.132	22.663
3	162537.698	145759.883	83.274	84.261	34.428	34.445
4	140797.826	130415.241	82.004	83.437	33.432	33.429
5	169575.314	161606.518	88.356	88.974	65.437	66.487
6	166898.557	160656.548	85.52	86.119	135.383	145.432
7	189896.867	182565.63	89.389	90.105	272.371	274.401
8	211235.593	208020.12	91.297	94.038	513.4	516.419
9	236905.307	234976.868	92.944	94.727	1112.441	1122.492
10	264318.255	262457.583	89.081	91.143	2452.429	2501.434

Our results showed that the adoption of RSCs rather than WPCs leads to a smaller ordering quantity of rewards, higher profitability (Fig. 2) and a smaller increase in the use of budget. Accordingly, the managerial implications are that when planning for reward supply, CLP managers should look for other methods, including contract type and collaboration mode, to deal with the demand uncertainty. They should not simply increase the ordering quantity of rewards, because this would result in the use of greater budget for point redemption and would ultimately be less profitable. Instead, they should consider other methods, including contract type and collaboration mode. The adoption of RSCs is recommended as a valuable tool for coalition loyalty program managers to mitigate the budget used for reward purchases, increase profitability, and manage the uncertainty of demand. By using RSCs, managers can achieve a balance between the ordering quantity of rewards and the budget used for point redemption, which is critical for the success of the coalition loyalty program.

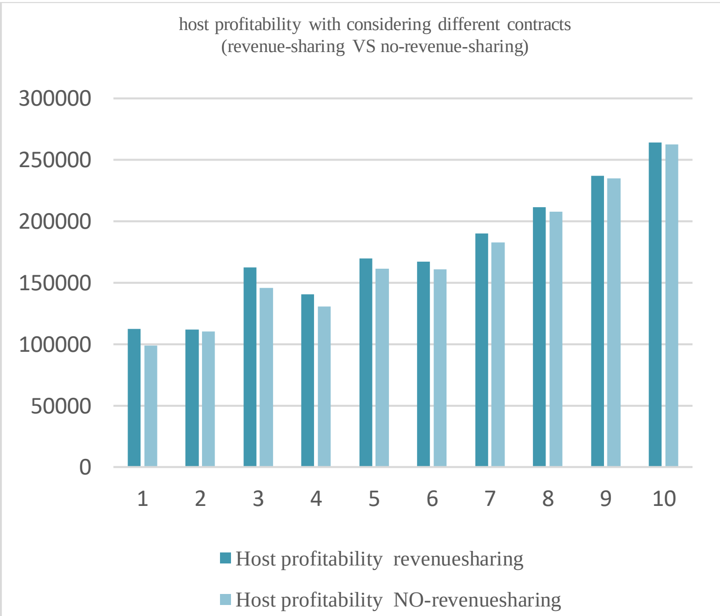
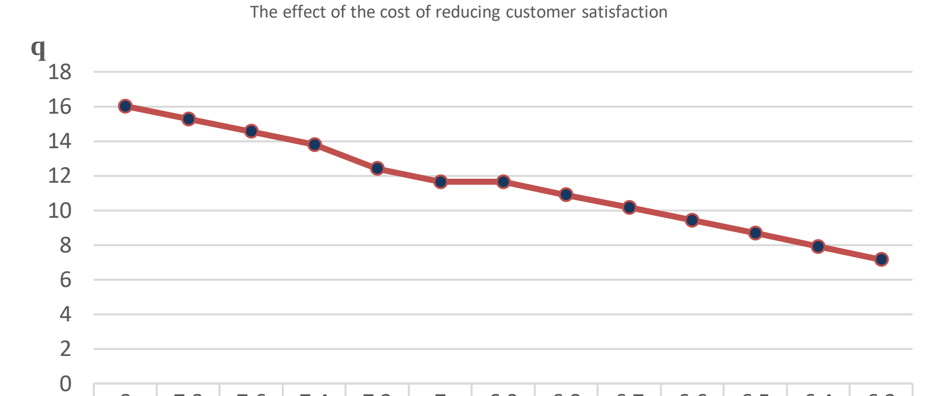


Fig. 2. Host profitability with considering different contracts (RS vs No-RS)



	8	7.8	7.6	7.4	7.2	7	6.9	6.8	6.7	6.6	6.5	6.4	6.3
q	16.02	15.28	14.56	13.79	12.4	11.65	11.65	10.89	10.16	9.42	8.68	7.9	7.15

Fig. 3. The effect of the cost of reducing customer satisfaction with considering RS contracts

5.3. The effect of the cost of reducing customer satisfaction on the optimal decision of the host

The cost of reducing customer satisfaction is a parameter that reflects the negative impact on customer satisfaction when a redemption partner runs out of rewards. It is important to note that a reduction in customer satisfaction can lead to a decrease in customer loyalty. Therefore, the importance of this issue for the LP host is significant. It is crucial to maintain a high level of customer satisfaction to retain customers and ensure the success of the LP program. Thus a sensitivity analysis can be conducted to examine how changes in v_j^R affect the optimal decision of the host. To perform a sensitivity analysis, we can vary v_j^R (Assuming an initial value of $v_j^R = 7$) within a reasonable range and observe how it affects the optimal order quantity of rewards from each redemption partner. Here, we assume that all other parameters remain constant. For simplicity of the calculations, the number of accumulation and redemption partners has been considered in the following form (1i=10, 2i=10, j=30). As shown in (Fig.3), if the cost of reducing customer satisfaction is high, the LP host may order more rewards from the redemption partner to prevent running out of rewards and potentially losing customers. On the other hand, if the cost of reducing customer satisfaction is low, the LP host may choose to order fewer rewards and risk running out of rewards, but save on costs.

To ensure that the order quantity of rewards is sufficient, the LP host can consider several factors, including historical demand data, current customer behavior, and the availability of rewards from each redemption partner. By analyzing historical demand data, the LP host can identify patterns and trends in customer behavior, such as the popularity of certain rewards or the frequency of redemptions. This information can help the LP host estimate the expected demand for rewards and determine the appropriate order quantity from each redemption partner R_j. Additionally, the LP host can monitor current customer behavior to identify any sudden changes in demand or unexpected trends. For example, if a particular reward suddenly becomes very popular, the LP host may need to increase the order quantity from the corresponding redemption partner R_j to ensure that there are enough rewards to meet the demand. Finally, the LP host should maintain regular communication with each redemption partner R_j to ensure that they have sufficient inventory to fulfill orders. This can involve sharing demand forecasts, discussing inventory levels, and collaborating on strategies to optimize the availability of rewards. By working closely with each redemption partner R_j and using data-driven insights, the LP host can ensure that the order quantity of rewards is sufficient to meet customer demand and avoid the risk of running out of rewards.

6. Conclusion

In conclusion, managing the reward and point supply chain in coalition loyalty programs is a complex task that requires careful consideration of several factors, including demand uncertainty, budget constraints, and contract types. The adoption of RSCs can provide a valuable tool for managing the ordering quantity of rewards and balancing the budget for point redemption. By using historical demand data, monitoring current customer behavior, and maintaining regular communication with redemption partners, CLP managers can ensure that the order quantity of rewards is sufficient to meet customer demand and avoid the risk of running out of rewards.

This article presents a comprehensive analytical model for effective planning of reward and point supply chains in LP programs. The model considers multiple managerial concerns such as budgeting and capacity limitations, demand uncertainty, and liability control under two types of contracts, RSC and WPC. The SAA-based two-stage approach is used to handle the stochastic demand, and the value of the stochastic solution is calculated to demonstrate the effectiveness of the approach. Moreover, the study evaluates the effects of the RSC-based contract structure on the LP program's performance and finds that RSC has positive effects on the profitability of the host and the quantity of rewards purchased by the host. Finally, the article emphasizes the importance of considering historical demand data, current customer behavior, and regular communication with redemption partners to ensure that the order quantity of rewards is sufficient to meet customer demand and avoid the risk of running out of rewards. In addition, CLP managers should consider other factors when planning reward and point supply chains such as; Redemption options, Customer experince. CLP managers should consider the types of rewards and redemption options they offer to customers. For example, they may offer a range of rewards that appeal to different customer segments or allow customers to redeem points for multiple types of rewards. This can help to increase redemption rates and customer satisfaction. They should consider the overall customer experience when planning reward and point supply chains. This involves ensuring that the redemption process is easy and convenient for customers, and that they are satisfied with the rewards and points they receive. By considering these factors, CLP managers can develop effective strategies for managing reward and point supply chains in coalition loyalty programs.

The article also suggests several directions for future research, such as extending the model to consider dependencies between parameters in different time periods, examining the distributions of point redemption and accumulation demands for different types of LRPs, and comparing the obtained solutions with other solution methods such as discrete event simulation.

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