Supply Chain Improvement Strategy with Extended Warranty on Retailers

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Abstract

This study demonstrates that an extended warranty is a signal of product quality and an improvement strategy in the supply chain. As one of the after-sales services, it assures customers and significantly contributes to the profits of manufacturers and retailers with a more extended warranty period than the base warranty. However, the extended warranty period imposes additional costs for the manufacturer and the retailer that might influence their profits. We address this concern by considering a manufacturer that offers base warranties to two retailers in the identical market segment. We propose two different strategies in this study. The first strategy is that retailers do not apply an extended warranty, while the second applies the contrary. Assuming that customers are risk-prone to an extended warranty, the results explain that the extended warranty strategy provides the supply chain with a higher profit than a strategy without an extended warranty. A manufacturer and retailers also benefit significantly from implementing an extended warranty strategy. Furthermore, numerical illustration and sensitivity analysis is performed for model verification and better understanding.

Keywords
Extended warranty, Retailer, Supply chain, Warranty model, Warranty strategy.

1. Introduction

A manufacturer implements a suitable strategy to attract more customers to compete and develop its business. Market competition and globalization provide more alternatives for customers in choosing products and services according to their wishes (Chu and Chintagunta 2011, Andriani et al. 2017). Manufacturers offer after-sales services or product support to guarantee, such as installation, warranty, maintenance service contract, training, and others. Customers also want assurance that the products and services they select will show satisfactory results and be helpful when operated correctly over the product's life (Zhu et al. 2018).

Warranty is an integral part of sales and one of the important factors after the customer purchases (Chen et al. 2009, Jindal 2014). Manufacturers who produce a product and service and retailers who distribute these products into customers' hands are also starting to pay attention. Warranty is a contractual agreement given by the manufacturer or retailer to customers who buy the product in replacement or repair if damaged during the warranty period (Otieno and Liu 2016a). Customers benefit from the existence of a warranty to protect them from defective products, and for manufacturers or retailers, the warranty limits irrational claims from customers (Estelami et al. 2016). In addition, manufacturers and retailers can take advantage of the warranty as an effective promotional instrument because products with a more extended warranty period provide a benchmark to customers that the product has better quality than the other products (Huysentruyt and Read 2010, Heese 2012).

The extended warranty market has been increasing consistently at 7% annually in the United States (Jindal 2014). Extended warranties extend the coverage of the manufacturer's warranty (Pan 2020). Selling extended warranties is also a fascinating source of profit for manufacturers and retailers (Gong et al. 2015, Liu et al. 2020). Not coincidentally, manufacturers and retailers are vigorously promoting extended warranties to customers more than ever before. However, providing a more extended warranty means incurring additional costs for manufacturers and retailers called warranty costs (Li et al. 2012, Jung 2019).

Numerous studies have investigated the topic of warranty cost modeling and policy under different circumstances. This study focussed on the warranty strategy for a manufacturer with two retailers in the identical market segment. The manufacturer offers customers a base free replacement warranty, wherein the manufacturer replaces the defective product during the warranty period. We propose two different warranty strategy models for retailers, as in the study of Bian et al. (2015) and Noval et al. (2016). Strategies I and II propose that both retailers do not provide and provide an extended warranty, respectively. The developed model aims to maximize the overall supply chain profit through strategic policies for retailers. To arrange the profit function, we determine the customer demand for each strategy. In addition, we also predict the level of product failure rate and estimate the costs incurred as proposed by Rahim and Fareeduddin (2011) and Esmaili et al. (2014). Therefore, the results are expected to support scientific contributions to similar studies and managerial contributions to manufacturers and retailers regarding the impact of the extended warranty strategy on supply chain profits.

We organize the rest of the paper accordingly. Section 2 explores the literature about warranties, extended warranties, and cost modelling for warranties. Section 3 describes our method, and the model is constructed. Section 4 illustrates a numerical example to validate our developing model and explain our analysis. We also perform sensitivity analysis. Finally, we conclude our results and provide several directions for future study.

2. Literature Reviews

One of the company's most promising after-sales services today is warranty service. The manufacturer's warranty service can impact the company's overall profit since executing after-sales services within the warranty term incurs warranty costs. One of the primary characteristics of warranties is whether they are renewable or not (Otieno and Liu 2016a). Whenever a product fails in the warranty period, a customer is compensated under warranty contract terms, and the warranty policy is renewed for another period. During the warranty period, there are several kinds of warranty policies, such as free replacement warranty, pro-rata warranty, or combination warranty (Otieno and Liu 2016b). However, during the post-warranty period, customers have to repair or replace the failed product at their own expense.

Offering an additional warranty to the customer has intensified the competition. The warranty is a contractual compensation regulated by the sales principle, and it has become a popular strategy to increase market demand by minimizing customer risks (Huysentruyt and Read 2010, Andriani et al. 2020). The warranty policy is closely related to product reliability (Zhou and Wang 2021). Customers can predict product quality based on the warranty length offered. If the product quality or reliability is excellent, the product warranty can be extended. As a result, the warranties policies promote customer purchase willingness and overall sales channel performance (Zhao et al. 2019). The extended warranty service is a repair service that extends after the warranty period. It is an optional purchase contract provided by a manufacturer, retailer, or third-party service provider (Pan 2020). It provides customers with access to repair after the warranty period, broadens the service market, and becomes a new source of profits for enterprises (Zhang et al. 2019). However, the warranty service performances also incur additional costs, including in every service performed (Tian et al. 2019). Excellent warranty service and policy management were essential to reduce the company's losses due to a warranty. Therefore, the primary goal for providing a warranty service period may be fulfilled without causing massive losses to the company (Vittal and Phillips 2007).

Despite customers' increasing trust in extended warranties, the study on the pricing of extended warranties is insufficient. Chen et al. (2009) and Jindal (2014) developed a model to determine how long the manufacturer warranty has to be in place to overcome customers' risk aversion, given that extended warranties are available in the marketplace. They confirmed that customers' ability to purchase extended warranties was more significant for more pricey products but not construct a demand model. Soberman (2003) discussed a scenario where a seller can utilize warranties to signal and filter simultaneously. He determined the best strategy for a high-quality seller who provided the base and extended warranties, and he conducted survey data to examine his predictions using a mathematical model. However, he also did not consider a demand model. Jiang and Zhang (2011) investigated how a manufacturer's decision to offer a standard warranty could be altered by the presence of extended warranty alternatives in the marketplace. They consolidated the influences of product failure probability to customers and demonstrated that a high-quality manufacturer would earn quality-signaling benefits by offering a manufacturer's warranty. They did not develop a demand model for the base and extended warranties like studies before.

Chen et al. (2009) investigated whether product attributes, retailer decisions, and customer characteristics impact the sales of extended warranties but did not explore the impact of base warranties. Esmaeili et al. (2014) also developed a structural demand model of base warranties but did not investigate the demand for extended warranties. More recently, Jindal (2014) published a study that we have known structurally estimating demand for extended warranty. His study's primary goal was to provide a clear empirical definition of the numerous underlying risk preferences that motivated customers to observe extended-warranty selections. However, neither of these studies considered the interaction between the base and extended warranties. All prior empirical studies on demand for extended warranties assumed that all customers were offered a single extended-warranty alternative.

The growing customer demand for extended warranties has provided tremendous profit-generating opportunities for numerous retailers, with profit margins in some instances much exceeding those of the items for which the retailer is best known (Chen et al. 2009, Zhao et al. 2019). Simultaneously, the downstream retailer aggressively promoted extended warranties to customers (Zheng and Ai 2017, Panda et al. 2020). Even though numerous operational and production models have been proposed to explain how extended warranties should be made available to customers, the study of extended warranties performed outside the manufacturer's warranty is limited.

To the best of our knowledge, relatively few studies have estimated the integrated demand model while considering manufacturer-based warranties and extended warranties nowadays. Chu and Chintagunta (2011) developed a demand model for channel intermediaries to assess the economic value of base warranties, but they did not establish a demand model for extended warranties. In contrast, Chen et al. (2009), Jindal (2014), Abito and Salant (2015), and Zhang et al. (2019) estimated demand models for extended warranties but did not address manufacturer-based warranties. Since empirical literature has discussed the base and extended warranty as independent markets, existing literature has not sufficiently explored how the provision of base and extended warranty interact. Therefore, this study fills a research gap by exploring the aforementioned research issues.

3. Research Methods

3.1 Problem Description

This study aims to construct a two-level supply chain warranty model, a manufacturer, and two retailers, without loss of generality. We develop a scenario with a manufacturer making and marketing their products through two retailers competing in the same market segment. The mathematical model development aims to maximize the overall supply chain profit by considering several parameters: demand, warranty costs, and the expected number of claims.

Manufacturers provide a base warranty with a free replacement warranty (FRW) policy, so there is no charge to replace damaged products with customers. The manufacturer's base warranty is provided with duration t_m and wholesale price w for the product. Meanwhile, retailers sell products to customers for p_i of the unit where i = 1, 2 denote the retailers. The retailers decide to offer or not to offer an extended warranty. If the retailers provide a more prolonged warranty, then there is an extended warranty, t_{ei}. On the other hand, the retailers will provide a base warranty from the manufacturer, t_m, so in general, $t_{ei} > t_m$.

Assuming there is no inventory in the market, the quantity purchased by the retailer is the quantity produced by the manufacturer, which is customers' demand q_i. The unit cost of each product produced by the manufacturer is represented by c_m. The retailers buy the product from the manufacturer at the wholesale price w with repair costs c_{ri} if providing the extended warranty. Then retailers sell it to the customer at the price p, so there is $p > w > c_m$, and we assume $c_m > c_{ri}$ for repairable products. Henceforth, the parameter marked with r and m is under the retailers and the manufacturer, respectively. The problem description is illustrated in Figure 1.

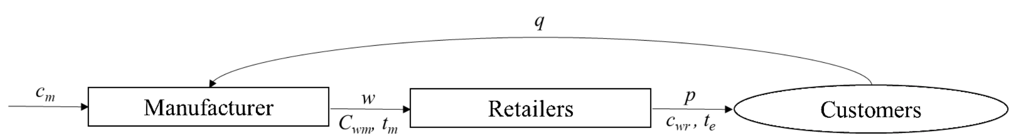


Figure 1. Schematic diagram for the retailer extended warranty scenario

3.2 General Model Development for Extended Warranty

In determining producer prices in wholesale price w, there are several influential parameters such as initial market size α, customer sensitivity to warranty length β, and competition θ between the two retailers i. We can formulate the function of customer demand q_i (i = 1, 2) in this model through these parameters. According to Bian et al. (2015), customer demand q_i depends on the retailer price p_i and the total length of the warranty t, i.e. the total length of the basic warranty t_m and the extended warranty t_{ei}. Customer demand q_i for the retailer i increase in the total warranty length for the product i ($t_m + t_{ei}$) and the price of the competitor's product with retailer price p_j (j= 1, 2). As in the research of Li et al. (2012), if we assume no information asymmetry between manufacturer and retailers, then the demand equation i is defined as follows:

$$q_{\mathrm{i}} = \alpha + \beta\,(t_i - \theta\,(t_j - t_i)) - p_i + \theta\,(p_j - p_i) \tag{1}$$

where $t_i, t_j = \begin{cases} t_m, & t_{e_i} = 0 \\ t_m + t_{e_i}, & t_{e_i} > 0 \end{cases}$

In addition to determining the demand function, we also determine the warranty cost c_w. In this scenario, we define warranty cost as the cost of the base warranty c_{wm} and the cost of extended warranty c_{wr} provided by manufacturers and retailers, respectively. The manufacturer provides a base warranty to the customer for free and bears the cost of a warranty c_{wm}. At the same time, retailers who do not offer an extended warranty also provide the base warranty by the manufacturer. On the other hand, the warranty costs for retailers who offer extended warranties c_{wr}.

The warranty cost can be estimated by the cost of reactivation multiplied by the number of claims N over a certain period. However, it is not possible to know the value of N deterministically, but it has to be calculated using a stochastic approach. Since we intend to investigate the warranty cost, we must estimate the expected number of claim E(N) during the warranty period. To conduct it, the failure rate λ of the product has first to be defined. The failure rate λ is critical in estimating the expected number of claims during warranty. This study uses the non-homogenous Poisson process (NHPP) and minimal repair to develop warranty cost models. Given a Poisson process $N(t)$ of rate $\lambda > 0$, suppose that each event has associated with it a random variable, possibly representing a value, an interval. After knowing the failure rate λ, we can determine the expected number of failures during a specific period. The expected number of claims on the manufacturer with the base warranty E(N_m) and the retailer with the extended warranty E(N_r) can be defined as follows:

$$E(N_m) = ½\, \lambda\, t_m^2$$

$$E(N_{ri}) = ½\, \lambda\, (t_{ei} - t_m)^2$$

Therefore, for product i, the manufacturer's base warranty cost c_{wm} is as follows:

$$c_{wm} = (c_m - s) \times E(N_m) \tag{2}$$

s is the salvage value of the production of each unit as described in Chien et al. (2014), and $E(N_m)$ is the expected number of claims during a certain period on the manufacturer. Meanwhile, the warranty costs for extended warranty offered by retailers are as follows:

$$c_{wri} = c_r\, E(N_{ri}) \tag{3}$$

where c_r is the cost of repair, while $E(N_r)$ is the expected number of claims during the extended warranty period offered by the retailer. Conclusively, we can formulate a profit objective function for manufacturers π_m, retailers π_{ri}, and the entire supply chain Π with the parameters as mentioned earlier in (2) and (3) are as follows:

$$\max \pi_m = q_i\, (w - c_m - c_{wm}) \tag{4}$$

$$\max \pi_{ri} = q_i\, (p_i - w - c_{wri}) \tag{5}$$

$$\max \Pi = \pi_m + \sum_{i=1}^{2} \pi_{r_i} \tag{6}$$

Furthermore, decision-makers with a centralized scheme aim to maximize overall supply chain profits by comparing supply chain profits from retailers that provide or do not provide an extended warranty. The following section will present the models developed for the extended warranty at retailers in more detail.

3.3 Decision Model for Extended Warranty Strategy on Retailers

In this section, we propose two strategies to compare the impact of extended warranty on retailers, i.e., Strategy I and II, where the retailers do not extend and extend the warranty, respectively. The objective functions in this study optimize the profit for manufacturers, retailers, and the supply chain with different strategies. The manufacturer and entire supply chain profit equations can be calculated using (4) and (6). Moreover, in more detail, we develop customer demand and retailer profit functions based on (1) and (5) for each strategy.

1. Strategy I: Retailers do not provide the extended warranty.
   - Customer demand at retailer

$$q_{i1} = \alpha + \beta\, (t_m - \theta\, t_m) - p_i + \theta\, (p_j - p_i) \tag{7}$$

   - Retailer profit

$$\max \pi_{ri1} = q_i\, (p_i - w) \tag{8}$$

2. Strategy II: Retailers provide extended warranty
   - Customer demand at a retailer

$$q_{i2} = \alpha + \beta\, (t_m + t_{ei} - \theta\, (t_{ej} - t_{ei})) - p_i + \theta\, (p_j - p_i) \tag{9}$$

   - Retailer profit

$$\max \pi_{ri2} = q_i\, (p_i - w - c_{wri}) \tag{10}$$

After developing the model according to the above strategies, we performed a numerical analysis to validate the models. The numerical analysis results are then used to formulate a warranty strategy that is profitable for the entire supply chain through strategic decisions on retailers.

4. Numerical Illustrations

We performed a numerical analysis to validate the model we developed earlier. In numerical analysis, we assign values to several parameters according to the strategy we propose on the mathematical model. In the demand function, we consider setting parameters as follows: $\alpha = 20$, $\beta = 0.5$, and $\theta = 0.55$. For players in the supply chain, we set the parameter settings for the manufacturer as follows: $c_m = 1.2$, $s = 0.4$, and $t_m = 1$. The setting parameter for Retailers 1 and 2 is $c_r = 0.8$, but the length of time extension for Retailers 1 and 2 is different, e.g. $t_{e1} = 1.5$ and $t_{e2} = 1.6$. This setting further investigates whether the warranty length will provide extra profits for different warranty extensions. The final parameter for the entire supply chain is the product failure rate $\lambda = 0.6$.

By applying (7) and (9), the customer demand for each retailer in each strategy is developed as follows:

1. Strategy I
   - Retailer 1 $\quad q_{11} = \alpha + \beta\, t_m - p_1$
   - Retailer 2 $\quad q_{21} = \alpha + \beta\, t_m - p_2$

2. Strategy II
   - Retailer 1 $\quad q_{12} = \alpha + \beta\,(t_m + t_{e1} - \theta\,(t_{e2} - t_{e1})) - p_1 + \theta\,(p_2 - p_1)$
   - Retailer 2 $\quad q_{22} = \alpha + \beta\,(t_m + t_{e2} - \theta\,(t_{e1} - t_{e2})) - p_2 + \theta\,(p_1 - p_2)$

In Strategy I, $t_{m1} = t_{m2}$ and $p_1 = p_2$, thus $\theta = 0$. Meanwhile, the profit for each retailer in each strategy is defined according to (8) and (10), as follows:

1. Strategy I
   - Retailer 1 $\quad \max\ \pi_{r11} = q_{11}\,(p_1 - w)$
   - Retailer 2 $\quad \max\ \pi_{r12} = q_{12}\,(p_2 - w)$

2. Strategy II
   - Retailer 1 $\quad \max\ \pi_{r21} = q_{12}\,(p_1 - w - c_{wr1})$
   - Retailer 2 $\quad \max\ \pi_{r22} = q_{12}\,(p_2 - w - c_{wr2})$

After calculating the optimal demand and profit for the retailer, we also calculate the optimal profit for the producer and the entire supply chain using (4) and (6). We get optimal results for the overall supply chain level, as shown in Table 1.

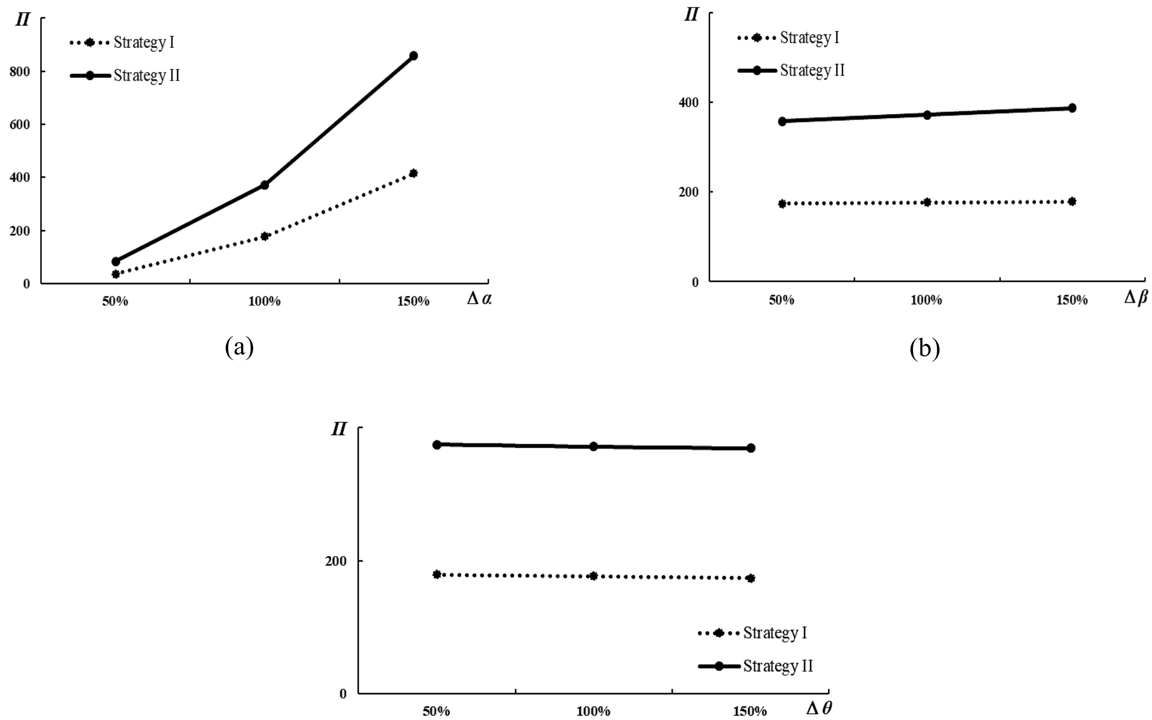
Table 1. The optimal solution for the extended warranty model at retailers

Strategy	Level	Parameter			
		p	q	π	Π
I	Retailer 1	10.83	9.39	37.08	176.44
	Retailer 2	10.83	9.39	37.08	
	Manufacturer	6.88	18.79	102.28	
II	Retailer 1	11.38	9.87	62.32	195.26
	Retailer 2	11.41	9.89	62.59	
	Manufacturer	5.00	19.76	70.35	

The optimization results in Table 1 show that the entire supply chain earns higher profits Π when offering Strategy II, extended warranty, than Strategy I. In detail, retailer 1 and retailer 2 have higher profits π in Strategy II than Strategy I, but the opposite condition applies to the manufacturer. At retailer 2, which offers a longer warranty extension than retailer 1, the profit obtained is slightly higher than retailer 1, 62.59 versus 62.32. Furthermore, we will conduct sensitivity analysis on several setting parameters to determine their effect on the developed model.

5. Sensitivity Analysis

In order to have a better understanding of the parameters and to help decide which strategy is better when dealing with situations, we provide sensitivity analysis in this section. We performed this analysis to determine the sensitivity of the parameters for the model we developed. The developed model has an objective function to maximize the entire supply chain profit. At the same time, the initial parameters that can affect the overall model developed are the parameters of the demand function. The parameters are α, β, and θ, representing initial market size, customer sensitivity to warranty length, and competition. To investigate how those parameters predispose the decisions between two strategies, we calculate each parameter with a different value while the others remain the same. Figure 2 shows the sensitivity analysis of each parameter to profit.



(c)

Figure 2. Sensitivity analysis on: (a) α, (b) β, and (c) θ

Parameter α describes the initial market size as the primary customer demand for retailers i. Figure 2(a) shows the profit for both strategies on α. We can observe that as α increases, the profit for both strategies also increases. Increasing market size will increase demand, meaning that product sales will also increase. The increase in sales will increase profits in both strategies, while Strategy II always has a higher profit than Strategy I in all conditions on α.

Figure 2(b) shows the profit for both strategies on β. Parameter β is the customer sensitivity to warranty length, conveying customers' willingness to bear higher prices when purchasing products with a longer warranty length. Increasing β influences in increased overall supply chain profits for both strategies. We can also observe that the increase in supply chain profit for Strategy II is more significant than Strategy I. It is triggered by retailers' offer of extended warranty in Strategy II. Meanwhile, Strategy I only provides a basic warranty from the manufacturer. Similar to the sensitivity analysis on α, Strategy II always shows higher profits than Strategy I.

The last parameter we investigate in the sensitivity analysis is the level of competition θ. The level of competition θ represents whether product substitution affects the optimal profit in the entire supply chain: the greater θ, the more intense the level of competition in the market. Figure 2(c) shows that changes in θ do not significantly impact changes in profit for each strategy. However, the profit difference between Strategy I and Strategy II is noticeable. The retailer's extended warranty is bundled with the product's price, so the competition between the two retailers directly affects customer demand and significantly impacts overall supply chain profits. In Strategy II, θ changes do not affect at all profits. Meanwhile, in Strategy I, θ changes slightly affect the entire supply chain profit decline.

The aforementioned analysis confirms that the extended warranty, Strategy II, impacts warranty decisions and the profits in the entire supply chain. It is noteworthy that we also assess several parameters in both strategies thru the developed model. We have compared the results, and we can see that changes in α and β have a significant effect on changes in profit. Meanwhile, competition θ further indicates that the extended warranty strategy significantly affects the entire supply chain profits. These understandings can serve as practical quantitative approaches for decision-makers to prioritize the parameter and design the warranty strategy in their supply chain.

6. Conclusions

We built a two-level supply chain warranty model, a manufacturer, and two retailers in the same market segment in this paper. The mathematical model was developed to maximize the overall supply chain profit by considering several parameters, i.e., demand, warranty costs, and the expected number of claims. According to the analysis, Strategy II, where the retailer delivers the extended warranty, results in more enormous profits of the entire supply chain than Strategy I, without providing the extended warranty. Moreover, the results show that the retailer offering the longer extended warranty earns more profits than the retailer proposing the shorter extended warranty. The manufacturer also gets higher profits when retailers offer extended warranties. It is because customer demand increases with the length of the warranty offered.

This study highlights the importance of warranty extension as one of the strategies in after-sales service. While an extended warranty can signal quality, this study confirms that an extended warranty strategy can increase profitability at all levels in the supply chain. By linking theory and practice, we offer these strategies to decision-makers across the supply chain to increase their business efficiency and profitability. However, we realize that our research is still limited and can develop in the future. Therefore, we propose several directions for future investigations, such as developing a stochastic demand model, adding other parameters, and adding levels or parties involved in the supply chain. In addition, we also suggest exploring the warranty strategy from the customer's viewpoint as a decision-maker.

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