Research on Compensation Mechanism for Two-Stage Delayed Delivery Problems Based on Whole Vehicle Logistics

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Abstract. With the continuous development of China's economic opening up to the outside world, the logistics market benefit expansion, the competitiveness of the automobile industry is more and more dependent on the service level of the vehicle logistics industry, so the efficient automobile distribution program has become the focus of attention of the logistics industry. Aiming at the problem that there are a lot of delays in the actual distribution, which leads to the decline of customer satisfaction, this paper proposes a compensation mechanism for delayed distribution to protect the rights and interests of customers. First of all, through the expected value model to solve the residual volume that does not meet the requirements of vehicle distribution and the randomness of the new phase demand; after that, according to the idea that the distribution cost saved by the logistics enterprise delayed distribution is compensated to the customer according to a certain proportion of the cost analysis, and established the compensation model of the first phase of the residual volume obeying different distributions; finally, combined with the case study to determine the compensation mechanism.

Keywords.full truck delivery; delayed delivery; compensation mechanism; expected value; stochastic programming

1 Introduction

Delayed distribution is a common situation of distribution, which largely hinders the development of the vehicle logistics industry. Delay was first proposed by Alderson [1], which is a comprehensive concept of marketing, manufacturing and logistics. Subsequently, Bucklin [2] explained the important role of delay strategy in inventory positioning in the market channel, and Shapiro [3] conducted a theoretical study on delay strategy positioning from the perspective of logistics, and established the relevance of supply chain and delay strategy. Until the 1990s, some high-tech enterprises and automobile manufacturing enterprises gradually pay attention to the theory of delay strategy and form a scale theoretical system.Budiman and Rau [4-5] proposed a two-stage stochastic model of supply chain network combined with delay strategy in order to solve the uncertain demand of the customers, and proposed a mixed-integer model of green supply chain network considering the delay strategy, and this model can reduce the cost under strict environmental policies.Phares and Jr [6] intervened in the supply chain uncertainty of a beer company and explored how the delay strategy can benefit the beer supply chain.Zheng, Shi

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and Wu [7] et al. explored the supply chain of standard and customized products in a manufacturer and retailer system with two ordering opportunities under the delay strategy. Weskamp [8] et al. proposed to hedge supply chain risk with delay strategy and constructed a two-stage stochastic mixed integer linear programming model to determine the decision considering lead time, penalty cost of shortages; Jabbarzadeh, Haughton, and Pourmehdi [9] proposed a two-objective robust optimization model to reduce the supply chain cost and reduce greenhouse gas emissions, which is used for integrated production and distribution planning in supply chains with delay strategies; Li, Wang and Cheng [10] developed an economic production quantity (EPQ)-based planned backordering model, which demonstrated that delay strategies can reduce the total average cost in some cases; Luo, Zhao and Song [11] pointed out the limitations and shortcomings of traditional delay strategies, and developed a model for service-oriented manufacturing environments. A delay strategy for service-oriented manufacturing environment was developed. Song, Li, Jun et al [12] considered the order delivery delay penalty and established a decision model integrating vehicle scheduling and order acceptance degree with the goal of maximizing the total profit. In the actual distribution process there is a large amount of randomness, to apply stochastic planning methods to solve.Budiman and Rau [13] proposed a two-stage stochastic model of supply chain network combined with the delay strategy to solve the uncertain needs of customers . In addition, Budiman and Rau [14]also proposed a mixed integer model of green supply chain network considering the delay strategy, so as to reduce the cost under strict environmental policies. Phares and Jr[15] intervened in the uncertainty of the supply chain of beer enterprises and explored how the delay strategy could benefit the beer supply chain . In the above analysis, the literature on delay compensation has two shortcomings: 1) the computational complexity of the pricing problem involved in the above literature is high, and the constraints are difficult to determine; 2) the above literature does not propose a specific compensation mechanism, and the reliability of the decision-making results can not be guaranteed.

2 Description of the problem

Delayed distribution is a distribution mode in the distribution strategy, refers to the time delay, the actual delivery of goods later than the customer specified delivery time, earlier than the latest delivery time, but also large-scale materials of the whole piece of distribution and the automotive industry, the most common problems in the whole car distribution. Third-party logistics companies will be transported to the car dealers, if a distribution cycle is divided into two phases, and to arrange for a time can be loaded with six cars of the truck for distribution operations. Requirements in a distribution cycle must be completed all orders, while meeting the full load of goods must be transported in a timely manner within a stage. Logistics companies receive orders, if the first stage to achieve full transport conditions on the distribution; if the end of the first stage there are still 2 cars left (the first stage of the remaining amount), it will be considered in the second stage of distribution. However, the delay in the delivery of customers have to wait longer, customer satisfaction with the logistics enterprise service is reduced, is not conducive to the long-term development of logistics enterprises, logistics enterprises need to compensate for the customer. This can be done by compensating customers for the distribution costs saved by the logistics company due to delayed distribution in a certain proportion.

For ease of discussion and description, the symbols are described as shown in Table 1 .

Table 1.Description of symbols

notation	significance
Q	Maximum loading capacity per delivery truck.
c	Single delivery cost per delivery truck.
θ	Compensation per delayed delivery sedan.
k	The amount of cars remaining at the end of the first stage, k = 1, 2, ----, Q-1.
ξ_n	Demand for automobiles in stage n,n=1, 2.
$F_1(k,\xi_2)$	denotes the cost function for the first stage of non-full delivery.
$F_2(k,\xi_2)$	denotes the cost function for the first stage of needy delivery.

Based on Table 1 and the distribution requirements of full load transportation, we found that determining the compensation pricing for delayed distribution in two stages requires considering three uncertainties, namely, demand, residual and loading at each stage simultaneously, so we propose the following model.

$$F_1(k,\xi_2) = \mathrm{int}(\frac{k+\xi_2}{Q})c + \delta(\frac{k+\xi_2}{Q})c \quad (1)$$

$$F_2(k,\xi_2) = c + \mathrm{int}(\frac{\xi_2}{Q})c + \delta(\frac{\xi_2}{Q})c \quad (2)$$

In (1), (2) int (x) represents the function of taking the integer, (x) represents the function of determining whether there is a remainder, x for the integer to take 0, x is not an integer to take 1.δ (x) that the function to determine whether there is a remainder, x is an integer 0, x is not an integer 1.

3 Compensation model based on distribution costs

According to the logistics companies to delay the distribution of distribution costs saved by a certain percentage of compensation to the customer's ideas, we are delayed distribution compensation pricing. In order to determine the compensation, we need to first determine the remaining sedan ride on the tailwinds can save how much distribution costs and under what circumstances can ride on the tailwinds, so the timely delivery and delayed delivery of the two cost functions to do the difference between the first stage of the remaining sedan delayed delivery of the distribution costs can be obtained when the distribution costs saved, we define$F_2(k,\xi_2)$ - $F_1(k,\xi_2) \triangleq \eta(k,\xi_2)$, then$\eta(k,\xi_2)$ to denote the saved distribution cost, since, the$F_1(k,\xi_2)$ and $F_2(k,\xi_2)$ the residuals k in k and, ξ_2 demand are random variables, there is no simple order relationship between random variables, we can not discuss directly. For this reason, we need to use mathematical expectation to deal with, if the probability distribution of the random variable is equal to the expected, after the expected value of the treatment is expressed as$E(F_2(k,\xi_2)) - E(F_1(k,\xi_2)) \triangleq E(\eta(k,\xi_2))$ If the probability distribution of the random variable is equal to the expected one, the expected value will be expressed as If we can discuss the$\eta(k,\xi_2)$ distribution, then we can find the cost savings of delayed delivery.$\eta(k,\xi_2)$ is a function of k and, ξ_2 Depending on the values of k and, ξ_2 different values of k and$\eta(k,\xi_2)$ also varies depending on the values of k and . We use θ to denote the unit compensation for delayed delivery of cars, and useλ We use θ to denote the unit compensation for delayed delivery of cars, and use θ to denote the proportionality coefficient of compensation to the customer for the distribution cost saved by the logistics enterprise. $\theta = \lambda E(\eta(1, \xi_2))$ when k=1, when k=2, compensation $\theta = \lambda E(\eta(2, \xi_2))$ When k=1, when k=2, the compensation, and so on, when k is any value (k is an integer), the compensation is $k\theta = \lambda E(\eta(k, \xi_2))$. The compensation function should be expressed as $E(k)\theta = \lambda E[E(F_2(k, \xi_2)) - E(F_1(k, \xi_2)]$ that is $E(k)\theta = \lambda E[E(\eta(k, \xi_2))]$ Firstly, E(k) is discussed, and then E(k) is analyzed in the following with a specific case. According to the previous data statistics, the ξ_1 obey π_1 distribution, the ξ_2 Obedience π_2 distribution(see table 2 and 3),the loading capacity of the vehicle Q=6,k=0, 1, 2, 3, 4, 5,the remaining capacity of the first and second stage ξ_n Obedience Pr(ξ_2 =i)=Pi distribution,i=0, 1, 2, 3, 4, 5, 6, 7.

Table 2.Distribution of demand in phase I

ξ_1	0	1	2	3	4	5	6	7
Pr(, ξ_1 Pr(=i)	$P_0^{(1)}$	$P_1^{(1)}$	$P_2^{(1)}$	$P_3^{(1)}$	$P_4^{(1)}$	$P_5^{(1)}$	$P_6^{(1)}$	$P_7^{(1)}$
π_1	0.1	0.05	0.05	0.1	0.15	0.05	0.25	0.25

Table 3 .Distribution of demand in phase II

ξ_2	0	1	2	3	4	5	6
Pr(ξ_2 =i)	$P_0^{(2)}$	$P_1^{(2)}$	$P_2^{(2)}$	$P_3^{(2)}$	$P_4^{(2)}$	$P_5^{(2)}$	$P_6^{(2)}$
$\pi_2 \frac{n!}{r!\,(n-r)}$	0.15	0.05	0.1	0.05	0.15	0.25	0.05

Based on the analysis of the distribution of phase I requirements, it is possible to summarize the distribution of phase I surpluses, as shown in table 4.

Table 4. Distribution of Phase I Surplus

k	0	1	2	3	4	5
Pr(, ξ_1 =i)	$P_0^{(1)} + P_6^{(1)}$	$P_1^{(1)} + P_7^{(1)}$	$P_2^{(1)}$	$P_3^{(1)}$	$P_4^{(1)}$	$P_5^{(1)}$
π_1	0.35	0.3	0.05	0.1	0.15	0.05

According to Table 4, the distribution of the first stage surplus and the expectation of the first stage surplus can be obtained, and the expectation of the first stage surplus is

$E(k)=(P_1^{(1)} + P_7^{(1)}) + 2P_2^{(1)} + 3P_3^{(1)} + 4P_4^{(1)} + 5P_5^{(1)}$ The maximum value of the first stage residual k is related to the loading capacity of the distribution vehicle. The maximum value of the first stage residual k is related to the loading capacity of the distribution vehicle, if the maximum loading capacity of the distribution vehicle is d, then k=d-1, at this time, the distribution of the first stage residual is $P_{d-1}^{(1)} + P_{2d-1}^{(1)}$ The first stage of the distribution of the remaining volume is. This can be obtained, the first stage of the distribution of the remaining amount of law is $P_k^{(1)} + P_{k+d}^{(1)}$ Therefore, the expectation of the first stage of the remaining amount is

$$E(k)=k\sum_{k=1}^{d-1}(p_k^{(1)}+p_{k+d}^{(1)}) \quad (3)$$

Based on $E(k)\theta=\lambda E[E(\eta(k,\xi_2))]$, E(k) is now obtained, and if it can be obtained $[E(\eta(k,\xi_2))]$ can be compensated. In order to obtain $E(\eta(k,\xi_2))$, combined with Table 2-4 we organize the distribution of the $\eta(k,\xi_2)$ the distribution of the distribution, as shown in Table 5.

Table 5. Q=6,k=0, 1, 2, 3, 4, 5.ξ_2 Obey $Pr(\xi_2=i)=Pi$ Table of expected savings

k	1	2	3	4	5
$E[\eta(k,\xi_2)]$	$\sum_{i=1}^{5}(p_i^{(2)}+p_7^{(2)})c$	$\sum_{i=1}^{4}(p_i^{(2)}+p_7^{(2)})c$	$\sum_{i=1}^{3}(p_i^{(2)}+p_7^{(2)})c$	$\sum_{i=1}^{2}(p_i^{(2)}+p_7^{(2)})c$	$(p_i^{(2)}+p_7^{(2)})c$

Combined with Table 5, it can be summarized that $\eta(k,\xi_2)$ For the different values of k, the values of $\eta(k,\xi_2)$ for different values of k, the values are also different. If we simply use $E(\eta(k,\xi_2))$ to express the expected value, can not clearly indicate the order of the random variable to take the expected value, the second stage of the residual amount of ξ_2 In this case, the expectation of the second stage residual is taken first, and then the expectation of the first stage residual k is taken, so we specify that $E(\eta(k,\xi_2))=M(k)$ denote the expectation of the second stage residual quantity, and use d to denote the loading capacity of a distribution vehicle, through the above analysis can be obtained. $M(k)=\sum_{1}^{d-1}k(\sum_{i=1}^{d-k}p_i^{(2)}+\sum_{i=d+1}^{m-i}p_i^{(2)})c$ The above analysis can be obtained. The demand of each stage has no influence on each other and is independent of each other. k is the residual quantity of the first stage, which is only related to the demand of the first stage, so k and k are independent of each other.ξ_2 is independent of each other, E[M(k)] can be expressed as E[M(k)]=p(k=1)M(1)+...+p(k=5)M(5). The combined analysis leads to the specific expression of E[M(k)] as

$$E[M(k)]=\sum_{K}^{d-1}[k(p_k^{(1)}+p_{k+d}^{(1)})(\sum_{i=1}^{d-k}p_i^{(2)}+\sum_{i=d+1}^{m-i}p_i^{(2)})c \quad (4)$$

by $E(k)\theta=\lambda E[E(\eta(k,\xi_2))]$, i.e. $E(k)\theta=\lambda E[M(k)]$ we can get $\theta=\lambda E[M(k)]/E(k)$, Models (3) and (4) denote E(k) and E[M(k)], respectively, carried over to $\theta=\lambda E[M(k)]/E(k)$ model (5), i.e., the compensation pricing model, can be obtained. The expression for compensation is obtained as

$$\theta=\lambda\sum_{k=1}^{d-1}[kc(p_k^{(1)}+p_{k+d}^{(1)})(\sum_{i=1}^{d-k}p_i^{(2)}+\sum_{i=d+1}^{m-i}p_i^{(2)})]/\sum_{k=1}^{d-1}k(p_k^{(1)}+p_{k+d}^{(1)}) \quad (5)$$

In model (5), $(p_k^{(1)}+p_{k+d}^{(1)})$ denotes the probability of occurrence of different residuals in the first stage, and $kc(\sum_{i=1}^{d-k}p_i^{(2)}+\sum_{i=d+1}^{m-i}p_i^{(2)})$ denotes the expectation of saving distribution cost when delaying distribution, $kc(p_k^{(1)}+p_{k+d}^{(1)})(\sum_{i=1}^{d-k}p_i^{(2)}+\sum_{i=d+1}^{m-i}p_i^{(2)})$ denotes how much distribution cost can be saved when the residual quantity in the first stage is k.

4 Case analysis

Combining model (3-5) with the data in the table above, the step-by-step calculation shows that the expectation of the first stage surplus $E(k)=1.55$ and the savings in distribution costs $E[M(k)]=0.688c$ when Q=6,k=0, 1, 2, 3, 4, 5.ξ_1 Obey π_1 distribution, the ξ_2 Obey π_2 Compensation when distributionθ =0.668λ c/1.55=0.44λ c(λ Proportionality coefficient of compensation to the customer for the distribution costs saved by the logistics company).

The next section discusses the effect of different values ofλ values on the compensationθ of compensation, the$\hat{\theta}$ It shows the compensation relationship under different values ofλ values of compensation, as shown in Table 6.

Table 6. Compensation pricing table

c	6000			8000			10000		
λ	0.5	0.7	1	0.5	0.7	1	0.5	0.7	1
$\hat{\theta}$	0.222c	0.312c	0.444c	0.222c	0.312c	0.444c	0.222c	0.312c	0.444c
θ	1332	1872	2664	1776	2496	3552	2220	3120	4440

Combining Tables 2-3 and 6, it is easy to find that when theξ_1 , theξ_2 the distribution is determined, the value ofθ The value is not only affected byλ (compensation ratio coefficient), but also by the cost, with the increase of cost, compensation also increases, according to the compensation coefficient of the different values of compensation also changes, at the same time, with the first stage of the surplus and the second stage of the demand expectation increases, compensation also increases. In short, cost is positively proportional to compensation, compensation is linearly proportional to the compensation ratio coefficient, and compensation is positively proportional to the expectation of the first-stage surplus and the second-stage demand.

5 Summary

This paper discusses the compensation pricing problem under different distributions of the first-stage residual volume, and comprehensively finds that 1) the delayed distribution compensation model based on distribution cost has good operability and interpretability; 2) the compensation factor is increased, which saves a certain proportion of distribution cost of logistics enterprises by comprehensively taking into account the interests of logistics enterprises while safeguarding the rights and interests of customers. In the actual logistics there are a large number of two-stage and above problems, of which two-stage is the most common, in this paper discusses the two-stage delayed delivery compensation pricing problems based on the multi-stage can also be discussed. When the first stage has a surplus, at the end of the second stage will prioritize the distribution of the previous stage of the remaining volume, so that you can shorten the customer waiting time for customers to wait for only one stage, but if the end of the second stage is still not up to the requirements of the whole vehicle delivery, then the customer needs to wait for the time of the two phases, the delay in compensation in this case will be increased even more. Whether to compensate the customer on the basis of the multiplier of the compensation pricing of the two stages or to discuss the compensation pricing for multiple stages is also a question worth discussing.

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