A Decision Making in Third-Party Platform Purchasing Service Considering Logistical Factors

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Keywords: Third-party platform, Procurement outsourcing, Delivery time, Service pricing.

Abstract. This paper establishes a model for a two-level supply chain composed of one retailer and one third-party platform. The model describes that the platform participates in retailer procurement issues considering delivery time. The optimal decision of the third-party platform and retailer under different service decision modes is studied. The study concluded that centralized decision-making is superior to decentralized decision-making. Secondly, this paper also proves that the optimal delivery time under the two decision-making methods is consistent. The optimal delivery time is determined by the market demand structure and the cost characteristics, not affected by the form of third-party platforms and retailers.

Introduction

With the acceleration of the global economic integration, the competition between enterprises has become increasingly fierce. More and more enterprises will integrate external professional resources, outsourcing a certain function to a third-party enterprise. The combination of third-party platform joint procurement and centralized warehouse allocation can effectively reduce the retailer's cost. Wei Lu [1] started from the current situation of China's procurement outsourcing, analyzed the opportunities and challenges faced by procurement outsourcing, and proposed some countermeasures for the development of China's new business model for third-party procurement services. Kinney [2] believes that whether the buyer or the seller builds a platform, the fairness of the transaction is difficult to guarantee, and the utilization rate of the platform is also limited. Chircu [3] defines a third-party platform built by a third party is an electronic place where multiple buyers and multiple sellers provide services. The integration of buyers and sellers with third-party platforms can make good use of the economies of scale of third-party platforms. Chen Xiang [4] studied the pricing strategy of attracting enterprises to apply third-party platform, pointing out that the third-party platform is very beneficial to the development of SMEs. In addition, Chen Xiangfeng [5] proposed that in the capital-constrained supply chain, 3PL can provide loans to under-funded retailers to help them purchase large-scale. Wang Yong, Hu Fei-fei [6] studied company outsources its order management to 3PL, the risk brought by uncertainty demand would be shared between the firm and 3PL. Zhou Jixiang [7,8] established a robust model of 3PL participation management procurement under partial demand information, and analyzed different procurement entities to changes and impacts of the profits of all parties in the decision-making process. The impact of delivery time on the profit of logistics service providers is two-way. It is an important decision-making problem to choose a balanced delivery time to maximize profits. So and Song [9] proposed that time and price to demand have a negative exponential relationship, Ray and Jewkes [10] assume that demand has a negative linear relationship with time and price. Then the researchers realized the necessity of cooperation in a complex competitive environment and examined the decision-making of the supply chain under the price-sensitive and time-sensitive conditions of demand.

Third-party platform procurement and third-party logistics services have a wide range of applications, but few studies combine the two on a third-party platform. Based on the research and analysis of scholars, we considered the demand structure and cost factors comprehensively and constructed the procurement service decision model considering logistics factors of third-party...
Mathematical Models for Purchasing Services Problems

Under the condition that demand is sensitive to time and price, enterprises use the price and logistics delivery time as a means of competition to gain more market share and profits. A two-level supply chain consisting of a retailer and a third-party platform is constructed in this paper. We assume that the retailer and the platform service provider are risk-neutral and the information is completely shared. Third-party platform can provide retailers with procurement and logistics services. The operational process structure is as shown in Fig. 1.

In general, the third-party platform will purchase for the retailer at a lower wholesale price $w$ than the retailer purchases alone, but the corresponding service fee $l$ will be charged. Since market demand is price and time sensitive, so it is assumed that both time and price are negatively correlated with demand, and this relationship is linear [9]. So the demand function satisfies the following expression:

$$d = a - b_1 p - b_2 t$$

Among them, $b_1 (b_1 > 0)$ is the price sensitivity factor to demand, and $b_2 (b_2 > 0)$ is the delivery time sensitive factor to demand. We assuming that the cost per unit of commodity storage and distribution is $n$, Guowei Hua [11] pointed out that the logistics cost and logistics time change in the opposite direction, and when the logistics time is short, the logistics cost will increase rapidly, when the logistics time is higher, the logistics cost will increase slowly, so the logistics cost of third-party platforms is set as follows: $n = \alpha + \beta / t$. Among them, $\alpha (\alpha > 0)$ is the logistics cost when the delivery time is so long, $\beta (\beta > 0)$ is a sensitive factor of delivery time to logistics costs.

Introducing parameters: $d$: The demand of good; $w$: The unit wholesale price of goods; $m$: The unit purchase service cost of goods; $n$: The unit logistics costs for third-party platforms; decision variables: $t$: Delivery time of goods; $p$: The unit sales price of goods; $l$: The unit purchase service price.

Third-party platform provide procurement and logistics services to retailers, and their revenue function can be expressed as:

$$\pi_S = (l - m - \alpha - \beta / t)(a - b_1 p - b_2 t).$$

(1)

The retailer outsources the procurement and logistics services to third-party platform service provider. Therefore, the retailer’s income function can be expressed as:

$$\pi_R = (p - l - w)(a - b_1 p - b_2 t).$$

(2)

Third-party Platform Procurement Service Decision Model Considering Delivery Time

Optimal Decision Making in Decentralized Decision Mode

Under decentralized decision mode, retailers and third-party platform are rational as independent entities, and both parties have made their own interests maximized to make decisions. In the
cooperation between the two, the decision-making process is a two-stage dynamic game. In the first stage, the third-party platform service provider chooses the optimal combination of service price \( l \) and delivery time \( t \) to maximize profit. In the second stage, the retailer decides the optimal sales price \( p \) according to service price and delivery time determined by the third-party platform. The optimization problem in the decentralized decision-making mode can be solved by the inverse induction method.

① Retailer’s optimal decision. Given the service price and delivery time of a third-party platform, depending on the retailer's income function, the retailer's optimization problem can be expressed as:

\[
\max \pi_r(p) = (p - l - w)(a - b_1p - b_2t).
\]  

(3)

Solving the first and second derivatives of \( p \) for the above formula (3):

\[
\frac{\partial \pi_r}{\partial p} = (a - b_1p - b_2t) - b_1(2p - l - w); \quad \frac{\partial^2 \pi_r}{\partial p^2} = -2b_1 < 0
\]

It can be seen from the above formula that the retailer's profit is a concave function about the sales price \( p \) in the case service price and delivery time are given, and there is an optimal price to makes the retailer's profit the largest. Let \( \frac{\partial \pi_r}{\partial p} = 0 \), the best sales price available:

\[
p^* = \frac{(a + b_1l + b_1w - b_2t)}{2b_1}.
\]  

(4)

② Third-party platform’s optimal decision. Assuming that internal information of the secondary supply chain is fully shared, the third-party platform can know in advance that the retailer will select the sales price according to formula (4). Combined with the income function, platform’s optimization problem can be expressed as:

\[
\max \pi_s(l, t) = \frac{1}{2}(l - m - \alpha - \frac{\beta}{t})(a - b_2l - b_1l - b_1w).
\]  

(5)

First we assume that the delivery time \( t \) is a fixed value and find the optimal service price \( l \). Solving the first and second derivatives of \( l \) for the above equations(5):

\[
\frac{\partial \pi_s}{\partial l} = \frac{1}{2}(a - b_2l - b_1l - b_1w) - \frac{b_1}{2}(l - m - \alpha - \frac{\beta}{t}); \quad \frac{\partial^2 \pi_s}{\partial l^2} = -b_1 < 0
\]

It can be seen from the above that the profit function of platform is a concave function of the service price \( l \), so there is an optional service price to make platform’s profit maximized. Let \( \frac{\partial \pi_s}{\partial l} = 0 \) so the best service price available:

\[
(a - b_2l - b_1l - b_1w) - b_1(l - m - \alpha - \beta/t) = 0.
\]  

(6)

At this point, assuming that the service price is fixed and the optimal delivery time is obtained. Solving the first and second derivatives of \( t \) for the above equation (5):

\[
\frac{\partial \pi_s}{\partial t} = \frac{\beta}{2t^2}(a - b_1l - b_1w) - \frac{b_1}{2}(l - m - \alpha - \frac{\beta}{t}); \quad \frac{\partial^2 \pi_s}{\partial t^2} = -\beta(a - b_1l - b_1w) < 0
\]

It can be seen from the above that the profit of platform service provider is a concave function of the delivery time \( t \), there is an optional delivery time to make platform’s profit maximized. Let \( \frac{\partial \pi_s}{\partial t} = 0 \) so the best delivery time available:
\[
\beta \frac{2l^2}{2b^2} (a - b_1 t - b_l - b_w) - \frac{b_2}{2} \left( l - m - \alpha - \frac{\beta}{t} \right) = 0. \tag{7}
\]

Combine the above two equations (6) and (7) to find the best service price and delivery time:

\[
l' = \frac{a - b_1 (w - m - \alpha)}{2b_1}; \quad t^* = \sqrt{\frac{\beta b_1}{b_2}}. \tag{8}
\]

Substituting the formula (8) into the sales price formula (4), and obtaining:

\[
p^* = \frac{(3a + b_1 w + b_1 m + b_1 \alpha)}{4b_1}. \tag{9}
\]

Combine formula (8) and formula (9), we can get an equilibrium solution \( (p^*, l^*, t^*) \) for the optimal decision in decentralized mode.

**Optimal Decision Making in Centralized Decision Mode**

In the centralized decision-making mode, instead of considering the benefits of individual companies, the platform and retailers are considered as a whole, considering the maximization of overall interests, the system determines the best sales price \( p \) and the optimal delivery time \( t \) to make the overall profit optimal. So the optimization problem of centralized decision is expressed as:

\[
\max \pi = \left( p - w - m - \alpha - \frac{\beta}{t} \right) (a - b_1 p - b_2 t). \tag{10}
\]

First assuming delivery time \( t \) is fixed and obtaining the optimal sales price \( p \). For the first and second derivatives of \( p \) in the above equation (10):

\[
\frac{\partial \pi}{\partial p} = (a - b_1 p - b_2 t) - b_1 \left( p - w - m - \alpha - \frac{\beta}{t} \right); \quad \frac{\partial^2 \pi}{\partial p^2} = -2b_1 < 0
\]

From the above, it can be seen that the system profit is a concave function about the sales price, there is an optimal sales price that maximizes the profit. Let \( \frac{\partial \pi}{\partial p} = 0 \), we can obtain:

\[
(a - b_1 p - b_2 t) - b_1 \left( p - w - m - \alpha - \frac{\beta}{t} \right) = 0. \tag{11}
\]

Then assume that sales price \( p \) is fixed and find delivery time is optimal. For the first and second derivatives of \( t \) in the above equation (10):

\[
\frac{\partial \pi}{\partial t} = \frac{\beta}{t} (a - b_1 p - b_2 t) - b_2 \left( p - w - m - \alpha - \frac{\beta}{t} \right); \quad \frac{\partial^2 \pi}{\partial t^2} = \frac{2\beta(a - b_1 p)}{t^3} < 0
\]

It can be seen from the above that the system profit is a concave function about the delivery time, there is an optimum to maximize the system profit. Let \( \frac{\partial \pi}{\partial t} = 0 \), we can obtain:

\[
\frac{\beta}{t^3} (a - b_1 p - b_2 t) - b_2 \left( p - w - m - \alpha - \frac{\beta}{t} \right) = 0. \tag{12}
\]

Combine the above two equations (11) and (12) to obtain the best sales price and delivery time:

\[
p^* = \frac{a + b_1 (w + m + \alpha)}{2b_1}; \quad t^* = \sqrt{\frac{\beta b_1}{b_2}}. \tag{13}
\]
Therefore, an equilibrium solution \( (p^*, t^*) \) in a centralized decision mode can be obtained.

**Analysis of the Benefits of Decentralized Decision and Centralized Decision**

The comparison of the two decision-making methods can be carried out in four aspects: delivery time, sales price, market share, and total profit. Assume that the optimal delivery time, sales price, market share and total profit under decentralized decision-making are \( t_1^*, p_1^*, d_1^*, \pi_1^* \); and the optimal delivery time, sales price, market share and total profit under centralized decision are \( t_2^*, p_2^*, d_2^*, \pi_2^* \).

**Proposition 1:** Under platform procurement service considering logistics factors, the delivery time is equal under decentralized decision and centralized decision. The best delivery time is \( t^* = \sqrt{fb_1/b_2} \).

The above proposition are available through comparing equations (8) and (13), indicating that the optimal decision of the delivery time is independent of the decision-making form, but rather sensitivity factor ratio of price and time and sensitivity factor of time cost.

**Proposition 2:** Regardless of decentralized decision or centralized decision, the optimal sales price is determined independently of the consumer's time-sensitive factor. When \( a/b_1 \geq (m + w + \alpha) \) is satisfied, the optimal sales price under decentralized decision-making is greater than that under centralized decision, the difference is \( a/4b_1 - (m + w + \alpha)/4 \).

Proof: according to formula (9) and formula (13)

\[
p_1^* - p_2^* = \frac{3a + b_1m + b_1w + b_1\alpha}{4b_1} - \frac{a + b_1m + b_1w + b_1\alpha}{2b_1} = \frac{a - b_1m - b_1w - b_1\alpha}{4b_1} = \frac{a}{4b_1} - \frac{(m + w + \alpha)}{4} \quad (14)
\]

**Proposition 3:** When \( a/b_1 \geq (m + w + \alpha) \) is satisfied, market demand under centralized decision is more than that under decentralized decision, and is not related to time-sensitive factors \( b_2 \).

Proof: according to equation (14)

\[
d_2^* - d_1^* = b_1(p_1^* - p_2^*) = a/4 - b_1(m + w + \alpha)/4 > 0. \quad (15)
\]

**Proposition 4:** When \( a/b_1 \geq (m + w + \alpha) \) is satisfied, the overall profit under centralized decision is more than profit under decentralized decision, and is not related to the time-sensitive factor \( b_2 \).

Proof:

\[
\pi_2^* - \pi_1^* = (a - b_1m - b_1w - b_1\alpha)^2/16b_1 = b_1(p_1^* - p_2^*)^2. \quad (16)
\]

Combined with the above propositions, the delivery time is not affected by the decision-making method, but only determined by the market demand structure and cost characteristics. And when \( a/b_1 \geq (m + w + \alpha) \) is satisfied, centralized decision is better than decentralized decision in aspects of sales price, market demand and system profit.

**Numerical Analysis**

In order to further analyze the optimal decision of platform procurement service considering logistics factors, this section tests the above models by numerical examples to provide an intuitive scientific basis and decision-making reference for decision makers. The relevant parameters in the model are specifically assigned as follows: \( a = 120 \), \( b_1 = 2 \), \( b_2 = 2 \), \( w = 20 \), \( m = 0.8 \), \( \alpha = 0.5 \), \( \beta = 4 \).

<table>
<thead>
<tr>
<th>Decision making method</th>
<th>( t^* )</th>
<th>( l^* )</th>
<th>( p^* )</th>
<th>( d^* )</th>
<th>( \pi_2^* (t^<em>, l^</em>) )</th>
<th>( \pi_R^* (p^*) )</th>
<th>( \pi (p^<em>, l^</em>, t^*) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decentralized</td>
<td>2</td>
<td>20.15</td>
<td>50.33</td>
<td>15.35</td>
<td>258.65</td>
<td>156.19</td>
<td>414.83</td>
</tr>
<tr>
<td>Centralized</td>
<td>2</td>
<td>40.65</td>
<td>34.7</td>
<td></td>
<td></td>
<td></td>
<td>602.05</td>
</tr>
</tbody>
</table>
From the above table, we can draw the following results: no matter what decision-making method, the delivery time has not been affected; the optimal sales price, market demand and system profit of centralized decision is greater than that of decentralized decision, and the theoretical value and the actual difference are same. The above verified propositions 1,2,3 and 4. In addition, from Proposition 1, the optimal delivery time decision is determined by the demand structure and cost characteristics. The price-to-time replacement rate reflects the characteristics of the market structure and represents the consumer's preference. The smaller the value, the more the consumer is time-oriented, and the other is price preference. Therefore, the numerical analysis will consider the impact of consumer time sensitivity on corporate decision-making.

On the basis of the above parameter assignment, let \( b_2 = 1, 2, 4 \), indicating that the consumer sensitivity to time is low, general and high. The results are shown in Table 2:

<table>
<thead>
<tr>
<th>( b_2 )</th>
<th>( t_1^* )</th>
<th>( t_2^* )</th>
<th>( p_1^* )</th>
<th>( p_2^* )</th>
<th>( d_1^* )</th>
<th>( d_2^* )</th>
<th>( \pi_1^* )</th>
<th>( \pi_2^* )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.83</td>
<td>2.83</td>
<td>50.35</td>
<td>40.65</td>
<td>16.52</td>
<td>35.87</td>
<td>456.17</td>
<td>643.38</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>50.33</td>
<td>40.65</td>
<td>15.35</td>
<td>34.7</td>
<td>414.83</td>
<td>602.05</td>
</tr>
<tr>
<td>4</td>
<td>1.41</td>
<td>1.41</td>
<td>50.33</td>
<td>40.65</td>
<td>13.69</td>
<td>33.04</td>
<td>358.71</td>
<td>545.92</td>
</tr>
</tbody>
</table>

From the table you can observed: Regardless of the consumers sensitivity to delivery time, the optimal delivery time of centralized decision-making and decentralized decision is the same; the optimal sales price, market demand and system profit of centralized decision is greater than that of decentralized decision, and the theoretical value and the actual difference are same; the more sensitive consumers are to the delivery time, the smaller the optimal delivery time. The above verified propositions 1,2,3 and 4. The more sensitive consumers are to delivery time, the more consumers are willing to pay higher prices for shorter delivery times, and consumers are time-sensitive. In face of this demand, companies should use short delivery times with higher prices as a means of competition. Conversely, if consumers are price sensitive, this market is a price-sensitive demand. At this time, companies can appropriately extend delivery time and reduce costs, and strive for a larger market share at a lower price. In the decentralized mode, the third-party platform maximized its own interests, reported excessive logistics prices, and suppressed customer demand. Although partial equilibrium was achieved, the overall situation did not reach optimal. Under the centralized decision-making model, the retailer as a whole considers the overall optimality and lowers the price to obtain a larger market. Obviously, enterprises in the centralized mode can better respond to market demands and survive and develop in the market competition.

**Conclusion**

This paper studies the third-party platform management enterprise procurement problem considering logistics factors. Under the condition of time and price sensitivity, a supply chain decision model that provides procurement services considering logistics factors are constructed, and the optimal decision-making scheme under different decision-making methods is obtained. Through the above analysis, first of all, centralized decision is superior to decentralized decision. In addition, the optimal delivery time under the two decision-making methods is consistent, and the optimal delivery time is determined by the market demand structure and the cost characteristics. Finally, after adding logistics factor into third-party platform procurement service, on the one hand, joint procurement by such
platforms can solve the problem of procurement for SMEs; on the other hand, the use of specialized logistics can promote market demand and improve enterprise efficiency.

This paper only considers the third-party procurement platform service decision with time-and price-Sensitive Demand. In the future, we consider platform service decision under random demand.

References


