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Research Article

Optimization Analysis of Supply Chain Resource Allocation in Customized Online Shopping Service Mode

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For an online-shopping company, whether it can provide its customers with customized service is the key to enhance its customers' experience value and its own competence. A good customized service requires effective integration and reasonable allocation of the company's supply chain resources running in the background. Based on the analysis of the allocation of supply chain resources in the customized online shopping service mode and its operational characteristics, this paper puts forward an optimization model for the resource allocation and builds an improved ant algorithm to solve it. Finally, the effectiveness and feasibility of the optimization method and algorithm are demonstrated by a numerical simulation. This paper finds that the special online shopping environments lead to many dynamic and uncertain characters of the service demands. Different customized service patterns and their combination patterns should match with different supply chain resource allocations. The optimization model not only reflects the required service cost and delivery time in the objective function, but also considers the service scale effect optimization and the relations of integration benefits and risks. The improved ant algorithm has obvious advantages in flexibly balancing the multiobjective optimizations, adjusting the convergence speed, and adjusting the operation parameters.

1. Introduction

As a means of circulation, the essence of online shopping [1–6] is to meet different customer needs by building integrated trading platform for information, funding, and logistics [2]. Within online shopping, different customized services (such as customized payment methods, shipping methods, and after-sale service methods) require online shopping companies to provide corresponding customized services; this capacity to provide customized service is acquired by supply chain network, which is led by online shopping companies (especially core businesses). This supply chain network mainly consists of online shopping firms, suppliers, third-party logistic companies, and other companies related to capital flows, such as banks and third-party payment platforms, which together form the online-shopping supply chain resources. Therefore, how to integrate and allocate supply chain resources based on different customers' individual needs directly determines the capacity of online shopping companies to provide customized services [1, 5].

Nowadays, online shopping has dramatically changed people's consumption habits. For example, in China, according to iReserach, the online shopping scale has reached 1.304 trillion yuan in 2012 with a year-on-year growth of 66.2%, and the number of online shoppers has reached 242 million with a year-on-year growth of 24.8%. Moreover, in 2012, China's mobile shopping scale has climbed to 55.04 billion with a year-on-year growth of 380.3%. Along with the rapid development of internet technology and mobile internet technology, more and more new ideas and modes have emerged in the online shopping industry, bringing online shopping firms with both opportunities and challenges, such as heated competition among companies, fierce price wars, complex and volatile industry environment, and upcoming reshuffle or integration. Those changes require online shopping companies to reposition their operation philosophy from a new perspective. Today, an increasing number of online shopping firms have realized that competing with extremely low prices is no longer an effective method; instead, meeting the individualized needs of their customers should be the strategic focus.

For example, JD.com and Yixun.com have been involved in the distribution sector in order to offer their customers better customized shopping experience; similarly, Amazon.com has carried out a service that the more you subscribe, the more you save. However, as the number of categories of online products and the number of customers keep increasing, and the needs for customization and diverse service keep elevating, online shopping companies face new challenges about how to improve supply chain flexibility in resource allocation, how to improve supply chain collaboration revenue and reduce corresponding risks, and how to effectively carry out the optimization under uncertain demand and other related issues.

What cannot be ignored is that online shopping firms are also facing some serious problems, such as the dissatisfaction of customers caused by "warehouse explosion" [6], a situation in which a company's ability to handle logistics cannot keep up with its customers' orders. There are mainly two main reasons that can account for this phenomenon: (1) customer needs change unexpectedly; (2) the allocation of supply chain resources does not keep up with customers' needs. Another example is the common credit issue (third-party logistic firms change products without permission and pack and distribute products barbarically and so on). Part of the reason lies in the unreasonable resource allocation and task scheduling.

All those problems prohibit current online shopping companies from improving its customer shopping experience. To solve those problems, it is crucial for companies to successfully match the integration and allocation of supply chain resources in its customized service mode. For online shopping businesses, simply establishing a beautiful and humane interface or efficient information system without efficient operation and effective integration of background supply chain resources is not feasible. Thus, it is of great importance to analyze the optimization of supply chain resource allocation in customized service mode of online shopping.

2. Related Work

Research on online shopping has been a new focus recently [1–8]. As the value and mode of online shopping, as well as other problems, have attracted general attention, supply chain operation in the online shopping environment has also come to light [1–3]. For example, the paper [2] defines the online shopping supply chain, pointing out that it consists of manufacturers, shop operators, logistic firms, and customers, and further studies the online shopping equilibrium model of supply chain constituted by those four levels. The paper [3], based on the former studies, analyzes the equilibrium and optimal conditions for decision makers on each level, as well as the conditions to reach systematic equilibrium, and finally gives some economic explanations. It should be noted that, unlike the traditional off-line supply chain operation [9, 10], the characteristics of online shopping customized services (especially when there are a variety of products and various customer needs) determine that the corresponding characteristics of customer needs are more dynamic and of high uncertainty [2]. This feature determines that to understand and deal with the randomness and uncertainty of supply chain resources allocation is of great concern, and how to deal with this kind of problem is also an important means to prevent and solve excess capacities and warehouse explosion which are common in online shopping practices.

Currently, the integration and allocation of supply chain resources under the dynamic and uncertain demand environment, among which systematic supply chain resource integration in uncertain environment [11], flexible scheduling of supply chain [12–16], and inventory control related to resource allocation [17] are several important research aspects, have drawn enough attention. For example, papers [11] investigate supply chain resource integration from the fourth-party logistics perspective and construct a decision-making optimization model and algorithm. Papers [14–16] mainly study dynamic optimization problem in the uncertain demand environment (mass customization) and set up allocation optimization model and algorithm. Although those studies mainly focus on manufacturing products, their ideas and methods for analyzing the optimization of resource allocation in the online shopping environment, which is a service product environment, have significant reference value.

3. Customized Service Mode of Online Shopping and Related Relationships

3.1. Customized Service Mode of Online Shopping. The customized services that online shopping companies provide to the consumers can be embodied in many aspects, such as the customizations of payment, the distribution methods, and after-sales service choices. And every aspect of customized service has several modes. For example, individual payment modes include online payment, cash on delivery, and virtual credit payment. As the Internet industry belongs to the emerging industry, all kinds of business philosophy and management styles change quickly, leading to the customized service mode of online shopping coming up endlessly. At the same time, the characters of electronic commerce environment give rise to various and widely distributed customers and quite different, complex, and volatile service requirements of the online company. Therefore, providing consumers with different shopping experiences not only relies on different service modes that the online company provides, but also reflects in the different service combination patterns, which is shown in Figure 1.

Obviously, the success of online shopping service not only requires different customized service modes of online shopping to match different allocations of supply chain resources but also requires different customized service combination modes to match the different allocations and combinations of supply chain resources. Since different customized service modes and corresponding combination modes need different characteristics, strengths, and relationships in between, it is necessary for the online company to carefully identify and screen the available supply chain resources in different service modes (and the combination modes), and find the best way to allocate those resources.

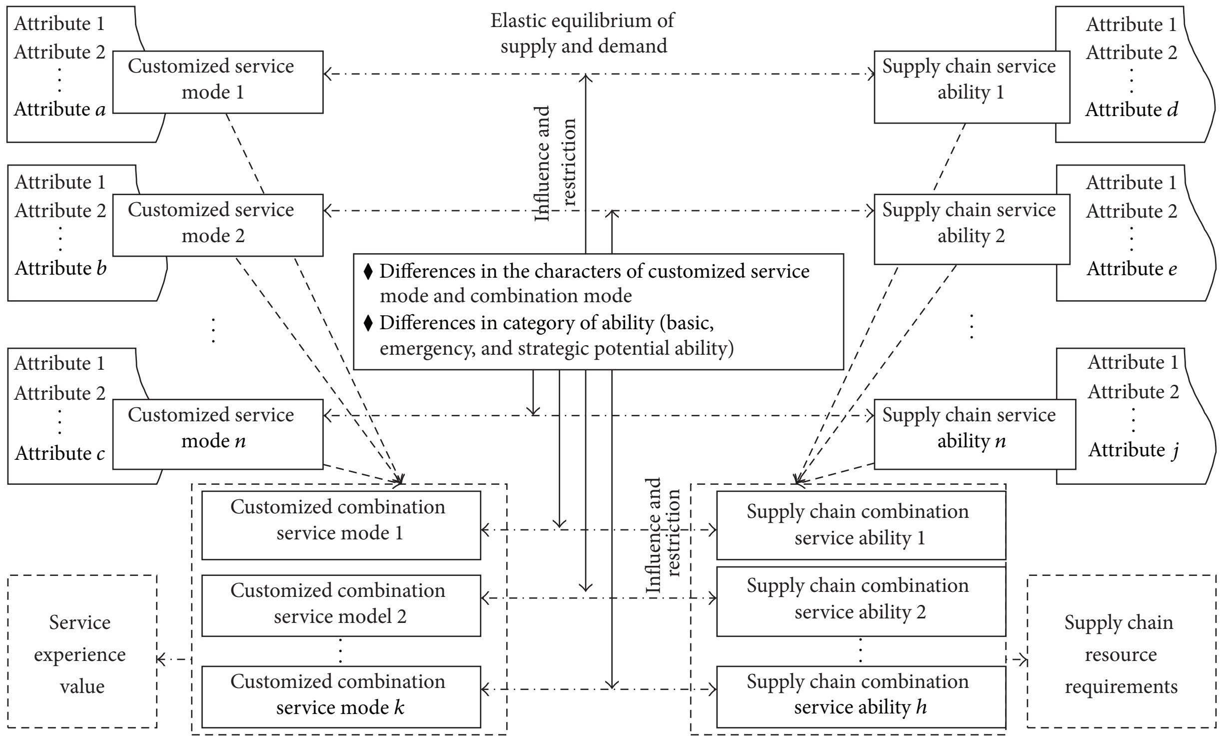


Figure 1: Elastic equilibrium of supply and demand ability.

3.2. Relationship between Supply Chain Resources of Online Shopping. The online company has to do the following work in order to provide consumers with customized service on its own e-commerce platform, including network interaction platform and supply chain support platform. First of all, the online company should grasp the different characteristics of consumers' customized service demand (including demand which can be expected and which cannot) and clear the specific requirements on the supply chain service ability to provide customers with different personalized service modes (and combination modes). Its purpose is to plan and allocate the necessary supply chain resources ahead of the requirements. Secondly, the online company needs to allocate the supply chain resources in accordance with the requirements that customized service modes bring up to supply chain service ability and determine the way to allocate supply chain resources under the different guidance of relations between supply (supply chain resources supply) and demand (customized service demand), so that it can allocate different consumers' customized service tasks to different supply chain resources rationally and realize the effective utilization of supply chain resources on the premise of meeting customized demands. Figure 2 briefly describes the supply chain resources relationship of the general online shopping company (core business).

4. Optimization Method

4.1. Assumptions. Considering characteristics of the allocation mechanism and resources interlinks with online shopping customized services, this paper makes following assumptions to construct the optimization model.

(1) N_0 denotes the total number of customer orders received by a core online shopping company in a certain period. I denotes the number of service categories defined by online shopping company to meet N_0 customized orders from when the task starts, and i denotes each category of service index ($i = 1, 2, \ldots, I$), meaning that in the i order set, there are M_i orders in total. j denotes the index of each order in the i order set ($j = 1, 2, \ldots, M_i$). Thus, for each customer order, it has a specific index (i, j).

(2) Suppose that according to the N_0 orders, online shopping company sets the starting time needed to meet those orders at t_s, and the total number of operation stages for the online shopping supply chain to accomplish those orders to be K (k is the index for each stage of K), which is showed in Table 1.

(3) Suppose that in K service provider stages, each stage has N_k cooperators. For those stages that online shopping company are involved in, suppose that each stage is divided into N_k business sectors (such as self-management logistic sector) and within in N_k cooperators; r denotes the index for each cooperators ($r = 1, 2, \ldots, N_K$). Thus, the index for the rth collaboration member in kth service providing stage is (k, r).

(4) In the online shopping environment, it is a necessary prerequisite to meet the basic needs of customer orders. In addition, as the needs for customized services deepen, customers' requirements for time get stricter. Therefore, suppose that $T_{D\cdot ij}(t_k)$ denotes the expected delivery lead time

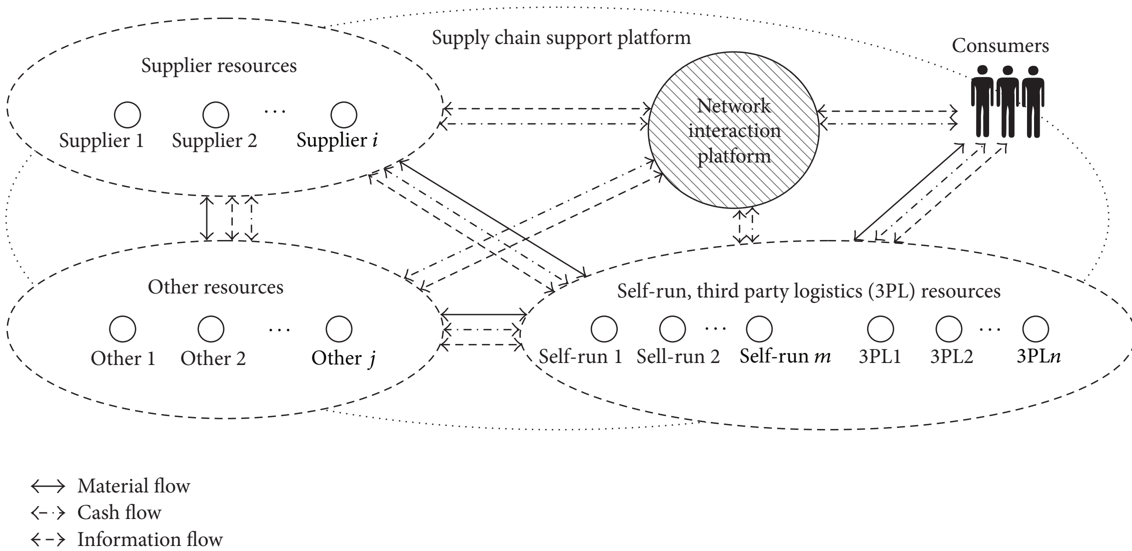


FIGURE 2: Types and basic relationships of online customized supply chain resources.

TABLE 1: Sample of operation stages in customized online shopping supply chain system.

Supplier service	Logistic service	Payment service	⋯	After-sale service
Supplier resource 1	1 (e.g., home delivery service)	1 (e.g., cash on delivery)	⋯	1 (e.g., on-site installation)
Supplier resource 2	2 (e.g., self-pickup service)	2 (e.g., POS on delivery)	⋯	2 (e.g., return pickup on-site)
Supplier resource 3	3 (e.g., mailbox)	3 (e.g., online payment)	⋯	3 (e.g., return at self-pickup post)
⋯	⋯	⋯	⋯	⋯
$k = 1$	$k = 2$	$k = 3$	⋯	$k = K$

for order (i, j) in stage k and $T_{kr\cdot ij}(t_k)$ denotes the operation time needed for the collaboration member (k, r) in stage k.

$T_{E\cdot kr\cdot ij}(t_k)$ denotes the expected processing time for collaboration member (k, r), which is determined by online shopping company according to both subjective and objective factors, to handle order (i, j) in stage k. Suppose that when order (i, j) is processed by member $(k + 1, r)$, the upper limit for the range of difference between the actual processing time and expected processing time is $T_{k+1\cdot ij}(t_k)$. Thus, from the perspective of processing time, rational allocation aims to achieve on-time delivery, which means that in every processing stage, the order is handled within the expected time requirement.

However, considering that there might be unexpected situations, such as traffic accidents, warehouse collapse in the supplier side, and other objective factors, this paper introduces the backordered tolerant coefficient λ, whose upper limit $\lambda_{\max}$ is set by all online shopping cooperators, in which $0 < \lambda < \lambda_{\max} < 1$. If an order cannot be completed with the promised delivery lead time, customers must be reimbursed.

(5) Suppose that the processing cost for collaboration member (k, r) to handle order (i, j) in stage k is $C_{kr\cdot ij}(t_k)$ and the maximum expected processing cost for collaboration member (k, r) to handle order (i, j) in stage k is $C_{E\cdot kr\cdot ij}(t_k)$.

(6) Suppose that when the order (i, j) is in stage k, the minimum spare service ability required for this stage is $A_{\text{dem}\cdot ij}(t_k)$, and for collaboration member (k, r) at time t_k in stage k, the spare ability for order (i, j) is $A_{\sup\cdot ij}(t_k)$. Similarly, when the order (i, j) is in stage k, the basic quality required for this stage is $Q_{\text{dem}\cdot ij}(t_k)$, and for collaboration member (k, r), the service quality required for order (i, j) is $Q_{\sup\cdot ij}(t_k)$.

(7) Suppose that the expected collaboration benefits for online shopping company to choose member (k, r) to handle order (i, j) is $E_{kr\cdot ij}(t_k)$, and the expected collaboration benefits for collaboration member (k, r) is $E_{c\cdot kr\cdot ij}(t_k)$, with $E_{c\cdot\min\cdot kr\cdot ij}(t_k)$ as the minimum acceptable value of the expected benefits. Suppose that at time t_k, the consolidated benefit satisfaction degree for the whole supply chain network is $E_{\text{sc}}(t_k)$, and the contribution factor for each member (k, r) to the consolidated benefit satisfaction degree is $\rho_{E\cdot kr}(t_k)$ $(0 \le \rho_{E\cdot kr}(t_k) \le 1)$. Different cooperators (k, r) possess different contribution factors; when the benefit preference satisfaction degree reaches the maximum, and all $\rho_{E\cdot kr}(t_k)$ equals 1, the consolidated benefit satisfaction degree achieves the ideal maximum.

(8) Suppose that the subjective collaboration risks for online shopping company to choose member (k, r) to handle order (i, j) is $R_{kr\cdot ij}(t_k)$, and the subjective collaboration risks for collaboration member (k, r) is $R_{c\cdot kr\cdot ij}(t_k)$, with $R_{c\cdot\max\cdot kr\cdot ij}(t_k)$ as the maximum acceptable value of the subjective collaboration risks. Suppose that at time t_k, the consolidated risk control satisfaction degree for the whole supply

chain network is $R_{\mathrm{sc}}(t_k)$, and the contribution factor for each member (k, r) to the consolidated risk control satisfaction degree is $\rho_{R\cdot kr}(t_k)$ $(0 \le \rho_{R\cdot kr}(t_k) \le 1)$. Different cooperators (k, r) possess different contribution factors; when the risk control satisfaction degree reaches the maximum, and all $\rho_{R\cdot kr}(t_k)$ equals 1, the consolidated risk control satisfaction degree achieves the ideal maximum.

(9) Define variable $g_{kr\cdot ij}(t_k)$. When online shopping company chooses member (k, r) to handle order (i, j), $g_{kr\cdot ij}(t_k) = 1$; otherwise, $g_{kr\cdot ij}(t_k) = 0$.

4.2. Optimization Model

Objective Functions. Consider

$$\min Z_1 = \sum_{k=1}^{K}\sum_{r=1}^{N_k}\sum_{i=1}^{I}\sum_{j=1}^{M_i}\left[C_{kr\cdot ij}(t_k)\, g_{kr\cdot ij}(t_k)\right] \quad (1)$$

$$\min Z_2 = \sum_{k=1}^{K}\sum_{r=1}^{N_k}\sum_{i=1}^{I}\sum_{j=1}^{M_i}\left[\left|T_{E\cdot kr\cdot ij}(t_k) - T_{kr\cdot ij}(t_k)\right| g_{kr\cdot ij}(t_k)\right] + \lambda \quad (2)$$

$$\min Z_3 = \left|\sum_{j=1}^{M_i} g_{kr\cdot ij}(t_k) - M_i\right| \quad (3)$$

$$\max Z_4 = \sum_{k=1}^{K}\sum_{r=1}^{N_k}\sum_{i=1}^{I}\sum_{j=1}^{M_i}\left[E_{kr\cdot ij}(t_k)\, g_{kr\cdot ij}(t_k)\right] \quad (4)$$

$$\min Z_5 = \sum_{k=1}^{K}\sum_{r=1}^{N_k}\sum_{i=1}^{I}\sum_{j=1}^{M_i}\left[R_{kr\cdot ij}(t_k)\, g_{kr\cdot ij}(t_k)\right] \quad (5)$$

subject to

$$\sum_{i=1}^{I}\sum_{j=1}^{M_i} A_{\mathrm{dem}\cdot ij}(t_k) \le \sum_{r=1}^{N_k} A_{\sup\cdot ij}(t_k) \quad (6)$$

$$T_{D\cdot ij}(t_k) \le \left[T_{kr\cdot ij}(t_k)\, g_{kr\cdot ij}(t_k)\right] \le (1+\lambda)\, T_{D\cdot ij}(t_k) \quad (7)$$

$$\left|T_{E\cdot kr\cdot ij}(t_k) - T_{kr\cdot ij}(t_k)\right| \le \max T_{k+1\cdot ij}(t_k) \quad (8)$$

$$\sum_{r=1}^{N_k}\sum_{i=1}^{I}\sum_{j=1}^{M_i} g_{kr\cdot ij}(t_k) = N_0 \quad (9)$$

$$\sum_{r=1}^{N_k} g_{kr\cdot ij}(t_k) = 1 \quad (10)$$

$$E_{c\cdot kr\cdot ij}(t_k) \ge E_{c\cdot\min\cdot kr\cdot ij}(t_k) \quad (11)$$

$$R_{c\cdot kr\cdot ij}(t_k) \ge R_{c\cdot\max\cdot kr\cdot ij}(t_k) \quad (12)$$

$$Q_{\sup\cdot ij}(t_k) \ge Q_{\mathrm{dem}\cdot ij}(t_k), \quad (13)$$

where $g_{kr\cdot ij}(t_k) = 0$ or 1; $k = 1, 2, \ldots, K$; $r = 1, 2, \ldots, N_k$; $i = 1, 2, \ldots, I$; $j = 1, 2, \ldots, M_i$.

4.3. Model Interpretation. Formula (1) is the optimization function to minimize the total cost for online shopping service; formula (2) is the optimization function for the on-time delivery of online shopping service. As a supply chain network, when online shopping company processes a certain order in the corresponding stage within the supply chain system, there is a corresponding expected processing time (expected delivery lead time). For customers, it is not always a good thing if the lead time is short; however, what really counts is the time lag between the delivery lead time and the expected delivery time for customers. The closer the actual processing time carried out by cooperators to the expected delivery time, the more likely to ensure on-time delivery, and at the same time, the more likely to enhance the stability of the system, to achieve the operational goal and to maximize the consolidated benefits for the whole supply chain network. Formula (3) is the optimization function of scale effect. For each collaboration member, the smaller the value of formula (3), the larger the bulk of processed orders, which are of the similar category within a certain time period, and the greater the scale effect. Formula (4) is the maximum optimization function for the expected collaboration benefits, which indirectly indicates that the online shopping company, the allocation subject, has predominant impact on the strategic orientation and determination for the collaboration relationship. Formula (5) is the minimum optimization function for the collaboration risks, which also indirectly indicates that online shopping company should understand both the current and potential collaboration risks faced by cooperators.

Formula (6) is the capacity constraint for providing online shopping service. Formula (7) is the constraint for the online shopping delivery lead time. Formula (8) is the constraint for the smoothness of each stage within online shopping service, which guarantees that a certain order runs smoothly among different stages. Meanwhile, this constraint also indirectly indicates that because all cooperators work in one supply chain network, when making decisions, they must take other members' benefits into consideration, and only in this way can the supply chain network as a whole achieve a rational collaboration relationship and accomplish online shopping service. Formula (9) is the constraint for each stage of online shopping service, which ensures that every order should pass all the processing stages (of course, in fact, some orders might not engage in certain stages of processing, which means they run through several virtual processing stages). Formula (10) is the ownership uniqueness constraint for online shopping, which ensures that each service task is done by corresponding collaboration member and there will be no repetition. Formula (11) is the constraint for the satisfaction degree about expected collaboration benefits, which ensures that the collaboration relationship is built on the expected benefit satisfaction for each collaboration member. Otherwise, they will not provide any online shopping service. Formula (12) is the constraint for the satisfaction degree about collaboration risk control, which ensures that the collaboration relationship is built on the expected risk control satisfaction for each collaboration member. Otherwise, they will not provide any online shopping service, either. Formula

(13) is the constraint for the quality of the online shopping service, which helps to meet the basic customer satisfaction.

5. Algorithm Interpretation

Because this model consists of several optimization objectives and constraints, this paper chooses ant algorithm [18, 19] that functions well (e.g., fast to converge to the global approximate optimal solution, easy to carry multifacet attributes of customized service) and solves those functions through corresponding design and improvement.

This algorithm regards each collaboration member in the supply chain as an individual service provider unit, and each unit has a corresponding operation parameter at each moment during the online shopping service processing time (the processing cost, processing time limit, expected collaboration benefits, and subjective collaboration risks, etc.).

Because different attributes of online shopping service determine that several cooperators need not be involved in a supply chain network, such as those who cannot meet the basic constraints (as shown in formula (6) to (13)), in order to accelerate the convergence of those nodes, this paper defines those nodes as the forbid nodes.

To meet customers' demand to the maximum degree, online shopping company must guarantee the punctuality of product delivery. For each stage of online shopping service, there is a required expected delivery lead time. Therefore, during the resource allocation, finding out the collaboration member that provides the closest lead time to the expected lead time at each stage is a critical optimization goal, which must be solved when constructing algorithms.

Another concern is the task flow congestion which might take place at some nodes when multiple order tasks are carried out by a supply chain member at the same time.

In order to ensure that the supply chain network as a whole can achieve the maximum consolidated benefits, it is required that no member should change the corresponding delivery time without permission after the task is allocated. Admittedly, cooperators can change its internal processing time in terms of other collaboration relationships.

Suppose that at a certain moment, the supply chain network is made up by source point, end point and collaboration member nodes in between. In the ant algorithm, an ant moves from the source point to the end point through the online shopping supply chain resource network and then dies, as shown in Figure 3. Since ants never come back, information in different paths is determined by the parameters of the task allocation among different cooperators. Algorithm constructions are as follows.

(1) This paper divides the ants based on two steps: firstly, according to the classification of customized online shopping order categories, each type of ants stands for a certain order category; secondly, according to the classification of the same customized service in different stages, different stages are represented by different types of ants. Thus, each type of ants denotes A_{ij} $(i = 1, 2, \dots I; j = 1, 2, \dots, K)$.

(2) For each type A_{ij}, since its demand attributes determine that the ants do not need to pass all the nodes, in order to accelerate the convergence, this paper defines those nodes as the forbid nodes for different types of ants.

(3) Define M_{ij} as feasible domain (the set made up by cooperators) for A_{ij} at time t_k. (kr) denotes the rth collaboration member at stage k $(k = 1, 2, \dots, K)$. Since one of the optimization goals for supply chain allocation is to minimize the processing costs, assume that the pheromone left by ants A_{ij} passing (kr) defined as $\pi_{ij\cdot kr}^{(1)}$ is inversely proportional to processing cost (C). Thus, the (1) type of attraction probability of (kr) to A_{ij} is

$$P_A^{(1)} = \frac{\pi_{ij\cdot kr}^{(1)}}{\sum_{r=1}^{N_k} \pi_{ij\cdot kr}^{(1)}}. \tag{14}$$

(4) Suppose that T_E is the expected time window for A_{ij} at stage k. Due to the dynamics of supply chain collaboration relationship, a certain member, who is also involved in other supply chain network, may adjust the processing time according to its own business stages. Suppose the time window that is provided to handle the online shopping service is T_S and denote that $T = |T_E - T_S|$. In order to finish the task on time and keep the coherence of different stages, the smaller the T the better. Sometimes, the value of T has something to do with the processing costs, requiring the supply chain system as a whole to judge unitedly. Assume that the pheromone left over after the ants A_{ij} pass (kr), which is defined as $\pi_{ij\cdot kr}^{(2)}$, is inversely proportional to (T). Thus, the (2) type of attraction probability of collaboration member (kr) to ants A_{ij} is

$$P_A^{(2)} = \frac{\pi_{ij\cdot kr}^{(2)}}{\sum_{r=1}^{N_k} \pi_{ij\cdot kr}^{(2)}}. \tag{15}$$

(5) Since one of the optimization goals for supply chain allocation is to maximize the collaboration benefits, assume that the pheromone left over after the ants A_{ij} pass (kr), which is defined as $\pi_{ij\cdot kr}^{(3)}$, is proportional to the expected collaboration benefits (E). Thus, the (3) type of attraction probability of collaboration member (kr) to ants A_{ij} is

$$P_A^{(3)} = \frac{\pi_{ij\cdot kr}^{(3)}}{\sum_{r=1}^{N_k} \pi_{ij\cdot kr}^{(3)}}. \tag{16}$$

(6) Since one of the optimization goals for supply chain allocation is to minimize the collaboration risks, assume that the pheromone left over after the ants A_{ij} pass (kr), which is defined as $\pi_{ij\cdot kr}^{(4)}$, is inversely proportional to the potential collaboration risks (R). Thus, the (4) type of attraction probability of collaboration member (kr) to ants A_{ij} is

$$P_A^{(4)} = \frac{\pi_{ij\cdot kr}^{(4)}}{\sum_{r=1}^{N_k} \pi_{ij\cdot kr}^{(4)}}. \tag{17}$$

(7) In order to solve the capacity constraints of cooperators and the scale effect of similar orders, repulsion

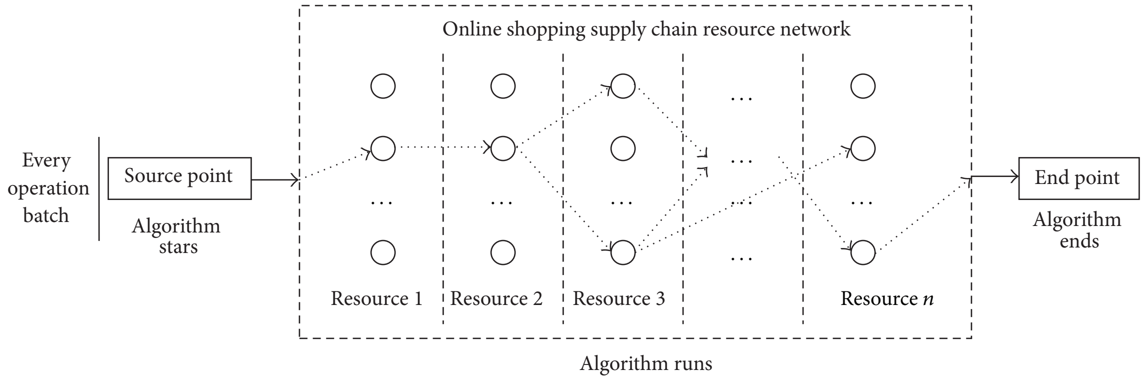


Figure 3: Sample for optimizing algorithm of every operation batch.

probability should be established to avoid possible ant-flow congestion or confusion of task assignment. Suppose that the pheromone left over after other ants expect for A_{ij} pass (kr) is $\rho_{pq\cdot kr}$, thus the repulsion probability for A_{ij} is

$$P_R = \frac{\rho_{pq\cdot kr}}{\sum_{r=1}^{N_k} \rho_{pq\cdot kr}}; \quad (p = i, q \neq j; p \neq i, q = j; p \neq i, q \neq j). \tag{18}$$

(8) Through (3) to (7), this paper defines that the comprehensive probability for ants A_{ij} to choose collaboration member (kr) is

$$P_{ij\cdot kr} = \omega P_A^{(1)} + \xi P_A^{(2)} + \psi P_A^{(3)} + \zeta P_A^{(4)} + \mu (1 - P_R), \tag{19}$$

where ω, ξ, ψ, ζ, μ $(0 < \omega, \xi, \psi, \zeta, \mu < 1; \omega + \xi + \psi + \zeta + \mu = 1)$ are adjustment factors, indicating the weighted expected coefficient of both attraction probability and repulsion probability.

(9) The pheromone update. Since the ants defined at this paper only move toward one direction, the update of the pheromone is automatically done by the algorithm itself. To illustrate the algorithm in a simpler way, let Φ denote $\pi^{(1)}$, $\pi^{(2)}$, $\pi^{(3)}$, $\pi^{(4)}$, and ρ; the update rule is

$$\begin{aligned} \Phi(t+1) &= \Phi(t) + \Delta\Phi(t, t+1) - \beta\Phi(t) \\ &= (1-\beta)\Phi(t) + \Delta\Phi(t, t+1), \end{aligned} \tag{20}$$

where $\Phi(t)$ and $\Phi(t+1)$ each suggest the total pheromone left over by ants passing through a certain collaboration member at t batch and $t+1$ batch; $\Delta\Phi(t, t+1)$ suggests the pheromone left over at $t+1$ batch; and β $(0 < \beta < 1)$ is the volatility coefficient of the pheromone.

For specific operation steps, please refer to paper [15].

6. Illustrative Example

An online shopping company DD mainly has two kinds of supply chain resources, namely, supplier (SUP) and the third party logistics company (3PL). There is more than one supplier that can provide similar products and they are distributed in different locations; each of those third party companies has its own logistics network, which basically covers the regions that online shopping consumers are in. The core activity of company DD is to provide consumers with different shopping experiences and satisfy their customized requirements in terms of price, time, and service. Because the individualized requirements of online shopping consumers have strong diversity and change quickly, and the cooperators are various and have complex relationships, company DD needs to choose cooperators and allocate online shopping tasks through complex and dynamic allocation activities of supply chain.

Now we select five suppliers that provide the same online products (shown as SUP1, SUP2, SUP3, SUP4, and SUP5) and five third party logistics enterprises (shown as 3PL1, 3PL2, 3PL3, 3PL4, and 3PL5) to demonstrate the illustrative example. According to the long-term and short-term strategic development requirements of the company DD, when allocating tasks to the above two kinds of cooperators it will emphasize several aspects, including cost and punctuality of corresponding online shopping tasks, the expected benefits from the collaboration and the subjective risk aversion. The company DD obtains the related operation parameters of all the cooperators (for the convenience of calculation, all the data in this section have gone through consistent-direction transformation, unit identification, and normalization procession) through a period of serious tracking investigation and scientific prediction, which is shown as Tables 2 and 3.

To some online shopping service task, given that the capacity requirements of task processing for the supplier is 0.8 and for the 3PL is 0.5, set the ant type for the supplier resource allocation to be class A and for 3PL resource allocation to be class B. Firstly we find that SUP3, 3PL1, and 3PL4 is not in conformity with the basic constraints, so we set them as forbid nodes.

(1) Supplier Resource Allocation. For online shopping company DD, on one hand, the supplier is the key to its cooperation strategy; thus choosing a suitable supplier that provides products of excellent quality can not only improve the satisfaction of online shopping consumers, the viscosity coefficient of the online shopping company and consumers but also reduce the cost of online shopping effectively and

Table 2: Supplier optimization parameter.

Resource allocation decision optimization parameter	SUP1	SUP2	SUP3	SUP4	SUP5
Online shopping task handling capacity	0.86	0.96	0.85	0.80	0.93
Processing cost (the larger the value, the smaller the cost)	0.76	0.64	0.66	0.72	0.70
On-time delivery (the larger the value, the more the punctuality)	0.55	0.46	0.45	0.49	0.52
Expected collaboration benefits (the larger the value, the greater the benefits)	0.60	0.63	0.62	0.54	0.61
Expected collaboration risks (the larger the value, the smaller the risks)	0.45	0.50	0.53	0.46	0.54
Expected collaboration benefits for cooperators (the larger the value, the greater the benefits)	0.60	0.57	0.48	0.47	0.46
The minimum expected collaboration benefits	0.50	0.45	0.50	0.38	0.33
The subjective collaboration risks for cooperators (the larger the value, the smaller the risks)	0.55	0.52	0.57	0.66	0.60
The maximum acceptable collaboration risks	0.53	0.50	0.56	0.60	0.58

Table 3: 3PL optimization parameter.

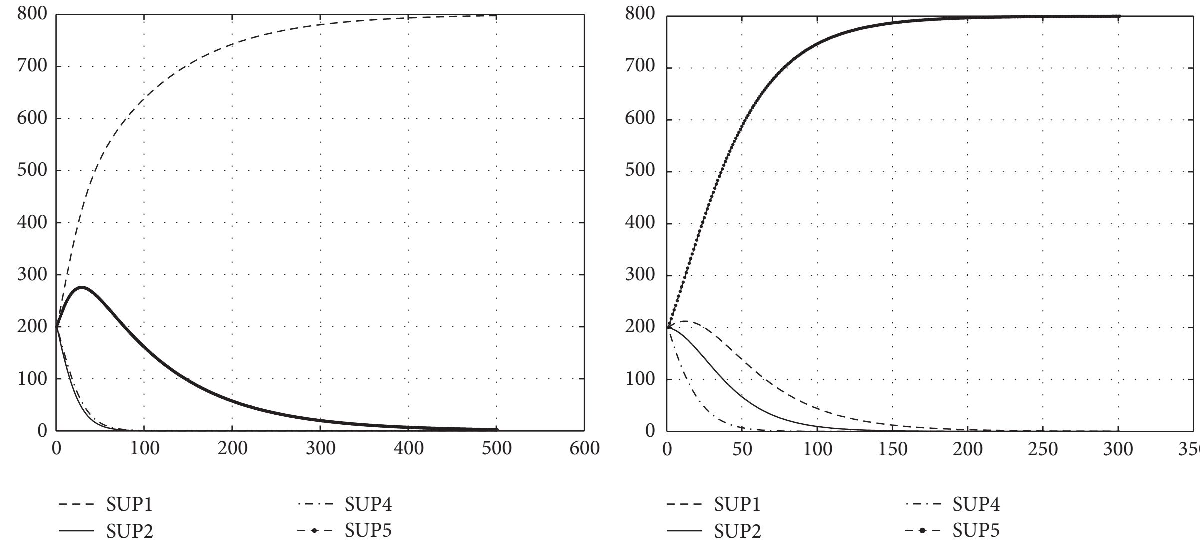
Resource allocation decision optimization parameter	3PL1	3PL2	3PL3	3PL4	3PL5
Online shopping task handling capacity	0.45	0.57	0.51	0.35	0.40
Processing cost (the larger the value, the smaller the cost)	0.55	0.52	0.53	0.49	0.50
On-time delivery (the larger the value, the more the punctuality)	0.32	0.35	0.37	0.28	0.30
Expected collaboration benefits (the larger the value, the greater the benefits)	0.38	0.38	0.40	0.41	0.33
Expected collaboration risks (the larger the value, the smaller the risks)	0.41	0.44	0.40	0.47	0.48
Expected collaboration benefits for cooperators (the larger the value, the greater the benefits)	0.30	0.42	0.61	0.48	0.49
The minimum expected collaboration risks	0.36	0.41	0.58	0.45	0.47
The subjective collaboration risks for cooperators (the larger the value, the smaller the risks)	0.45	0.52	0.46	0.50	0.51
The maximum acceptable collaboration risks	0.50	0.55	0.49	0.48	0.56

guarantee on-time delivery of online shopping. On the other hand, the cooperation between suppliers and the online shopping company is not only for profit in the cooperation, but for the long-term cooperation as well and gets more expected benefits and reduces the risks of future collaboration at the same time. Among them, how to elude the strategic risks of long-term cooperation and fusion risks (especially for the international supply cooperation) is an important problem on the premise of focusing on the culture, history, reputation, brand, scale, and market of the suppliers.

Here we discuss two kinds of situations. One is that because there are a lot of suppliers and the products provided by those suppliers have few differences in quality, assume that the online company DD mainly considers the processing cost and time of online shopping tasks when it sets the weight for supplier resource allocation optimization objectives. Choose the coefficient of the algorithm as $\omega = 0.4$, $\xi = 0.3$, $\psi = 0.2$, $\zeta = 0.1$, $\mu = 0$ (there is no capacity constraint), $\lambda = 0.1$; set ants batch as 500. Use MATLAB 7.1 R14 to make simulation and the convergence results are shown in Figure 4(a).

Another situation, suppose that the products that suppliers provide are important strategic ones for the online shopping company DD, which are the key products to enhance consumers' value, maintain consumers' viscosity and improve DD's competitiveness. Although there is more than one supplier that offers the same products, not all the suppliers have a long-term cooperation strategic value because of the difference in their historical reputation and cultural position. Therefore, the company DD tends to consider the expected benefits and cooperation risks based on the strategic consideration when it sets the weight for supplier resource allocation optimization objectives. Set the coefficient in the operation of the algorithm as $\omega = 0.2$, $\xi = 0.2$, $\psi = 0.3$, $\zeta = 0.3$, $\mu = 0$, and $\lambda = 0.1$, and ants batch as 500. The convergence results are shown in Figure 4(b).

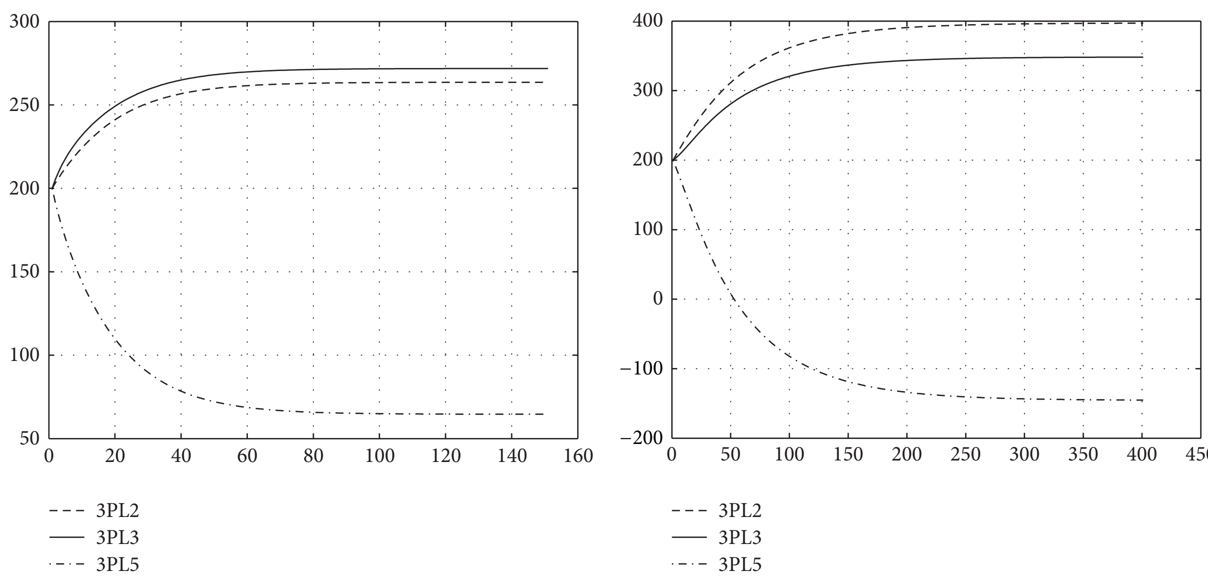
From the analysis of Figure 4(a), ants of type A reach steady state after several operation batches. All the ants



(a) Company DD goes for supply cost and time

(b) Company DD goes for cooperation benefits and risks

Figure 4: Results for supplier resource allocation.



(a) Company DD goes for logistic cost and time

(b) Company DD goes for cooperation benefits and risks

Figure 5: Results for 3PL resource allocation.

choose SUP1. This is because SUP1 has more advantages in terms of service processing costs and processing time limit. Unlike this, SUP5 embodies the trend of decline after rising first, which is because although this supplier also has an obvious advantage in terms of cost and time it is not better than SUP1.

For the situation shown as Figure 4(b), all the ants that reach steady state choose SUP5. This is because SUP5 has more advantages in terms of expected benefits and risk aversion when cooperating with the company DD, which meets the long-term strategic requirements of DD.

(2) 3PL Resource Allocation. 3PL is the important carrier for the online shopping company DD to realize noncore business outsourcing. With the development of the socialized logistics systems, there is an increasing number of 3PLs that can provide satisfactory consumers' logistic service, thus there is less long-term risks to cooperate with the 3PL enterprises. As a result, expected cooperation benefits are mainly determined by the online shopping task processing cost of the logistics and the way to guarantee the punctuality of logistics activities. Thus, set the coefficient in the operation of the algorithm as $\omega = 0.3$, $\xi = 0.4$, $\psi = 0.1$, $\zeta = 0.2$, $\mu = 0$, and $\lambda = 0.1$; set ants batch as 150. The convergence results are shown in Figure 5(a).

For the ant type B in Figure 5(a), after several operation batches, it reaches steady state. Most ants choose 3PL3 and

3PL2, while others choose 3PL5. This is because 3PL3 and 3PL2 are better than 3PL5 in terms of the processing cost and time of the logistics, which conforms to the strategic intent of the company DD. At the same time, choosing a number of 3PL companies can achieve the goal of risk aversion and elevate competitive benefits. Figure 5(b) shows the result that company DD goes for cooperation benefits and risks of logistics outsourcing (adjust the algorithm parameters as $\omega = 0.1$, $\xi = 0.2$, $\psi = 0.3$, $\zeta = 0.4$, $\mu = 0$, $\lambda = 0.1$, set the ant batches as 400), the result of which is clearly different with Figure 5(a).

7. Conclusion

Starting from the analysis of the characteristics of customized B2C online shopping service modes and of the dynamic equilibrium between different service demand modes (including their combination modes) and the capacity supply of the supply chain resources, this paper studies the optimization problems of supply chain resource allocation in customized online shopping service mode, which is different from the supply chain resource allocation under traditional manufacturing or service circumstances.

As an exploratory study about the supply chain operation in customized online shopping environment, this paper, from the perspective of supply-demand equilibrium, constructs the decision-making optimization model to solve resource allocation problems and discusses the solution method. The model proposed in this paper not only throws light upon major indicators of customer service value experience from the view of supply chain system, but also introduces the benefit and risk equilibrium relations of both cooperation sides.

The main conclusions of this paper are as follows.

(1) Characteristics of the customized service demands in online shopping determine that there are more obvious dynamic and uncertain characters of B2C online shopping demands. It is most important and valuable for us to understand and deal with the uncertainties in the online shopping supply chain resource allocation. How to deal with this problem is an important means to give preventions and treatments of the service capacity overstocks and storehouse explosions often generated in the online shopping practice.

(2) The success of online shopping service requires two essential matching relations. One is that different online shopping customized service patterns should match with different supply chain resource allocation schemes; the other is that different customized service combination patterns should also match with different supply chain resource allocation schemes.

(3) The characters, intensions, and the inner relations of the supply chain resources needed by different customized service patterns and their combination patterns are always different. It is necessary for online shopping companies screening and selecting carefully the supply chain resources for its different service patterns (including combination patterns) and finding the best ways of resource allocations.

(4) The establishment of supply chain resource allocation optimization model in online shopping customized service mode needs several special treatments of the objective functions. One is to reflect the service cost and delivery time relations in the optimization objective functions; the other is to consider the service scale effects at the same time. Moreover, how to introduce the supply chain cooperation benefits and risks into the optimization model are also very important.

(5) The ant algorithm based on ants' optimization mechanism of looking for food has the advantages of fast convergence to the global optimal solution and it is easy to carry representative multiattribute of customized service differentiations. Through the algorithm improvement, the supply chain resource allocation algorithm in online shopping customized services has great advantages in weighting multiobjective optimizations, in flexibly judging the convergence speed and in the flexibilities of parameter adjustment.

All these indicate that the supply chain resource allocation optimization in online shopping customized service environment are more complex but it really reflects the practical operations of the online shopping service activities and the complicated supply chain collaboration relations.

In future studies, the analysis about the core value of online shopping service modes strategically, about the two-way interaction decision on risk-benefit between online shopping companies and their supply chain cooperators, and about the dynamic match of supply-demand capacities will be the focus.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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