# Service Supply Chain Optimization Considering Moral Hazard and Additional Capacity

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**Abstract.** Service supply chains are characterized by demand uncertainty and information asymmetry, which may lead to moral hazard and inefficient capacity allocation. To address these issues, this study develops a service supply chain optimization model integrating moral hazard prevention and additional capacity decisions under a centralized decision-making framework. The model considers a service integrator and a service supplier, where the integrator adopts monitoring and penalty mechanisms to reduce opportunistic behaviors, while the supplier establishes additional capacity to respond to uncertain demand. Mixed-strategy Nash equilibrium analysis is employed to derive the optimal monitoring probability, supplier behavior probability, and additional capacity decisions. Numerical results indicate that centralized decision-making combined with additional capacity investment improves overall system performance. Specifically, under the numerical setting, the optimal additional capacity is 43.75 units and the service supply chain reaches its maximum profit of 6901. Sensitivity analysis further shows that penalty intensity, monitoring cost, profit-sharing ratio, and additional capacity cost significantly influence equilibrium decisions and total profit. The findings provide managerial insights for improving service quality and resilience in service supply chains.

**Keywords:** Service supply chain; Additional capacity; Moral hazard; Quality control; Risk sharing

## 1 Introduction

With the rapid development of globalization and digitalization, supply chain management has become a key strategy for firms to enhance competitiveness and achieve sustainable development. As an important branch of supply chain management, service supply chains (SSCs) have attracted increasing attention from both academia and industry. SSCs rely heavily on the coordination of information flow, service flow, and financial flow. They have been widely applied in industries such as retail, logistics, and finance. Since Ellram [1] first introduced the concept of the service supply chain, research in this area has continued to grow. However, compared with manufacturing supply chains, SSCs have a shorter development history. Their theoretical framework and practical applications are still evolving.


Z. Ge et al. (eds.), *Proceedings of the 2026 6th International Conference on Education, Information Management and Service Science (EIMSS 2026)*, Atlantis Highlights in Computer Sciences 25,
https://doi.org/10.2991/978-94-6239-766-8_12

At the same time, the market environment is changing rapidly. Customer demands are becoming more diverse and uncertain. Competition is no longer limited to individual firms but has expanded to the performance of entire supply chain networks. Therefore, improving service efficiency, reducing operational costs, and enhancing customer satisfaction have become critical objectives for SSC optimization. Existing studies mainly focus on individual aspects, such as cost reduction or efficiency improvement. However, they often overlook risks and resource constraints that are unique to service environments. In particular, limited attention has been given to the combined effects of moral hazard and additional capacity management.

Moral hazard is a common issue in supply chain collaboration. Its impact becomes more complex in service supply chains. Services are intangible, instantaneous, and difficult to evaluate quantitatively. As a result, integrators often face difficulties in setting unified service standards and monitoring service quality. Under information asymmetry, service providers may engage in opportunistic behaviors. Examples include reducing service quality, misreporting costs, and concealing important information for private benefits [2]. The principal-agent framework provides a possible way to mitigate these problems through contract design [3]. However, service characteristics make monitoring and implementation more difficult.

Another important issue is capacity management. Since services cannot be stored, matching supply with demand plays a critical role in SSC performance. Firms often invest in additional capacity to improve responsiveness and increase system resilience under uncertain demand conditions [4]. Appropriate additional capacity can reduce the impact of demand fluctuations. However, excessive capacity may lead to higher operating costs and resource waste.

More importantly, moral hazard and additional capacity decisions are closely related rather than independent [5]. On the one hand, suppliers' moral hazard behaviors, such as capability misrepresentation or insufficient effort, may distort demand and capacity information. This can further affect capacity planning and resource allocation [6]. On the other hand, governance mechanisms, monitoring policies, and additional capacity investments can change the costs and benefits of opportunistic behaviors. These factors therefore influence suppliers' strategic choices [7]. In addition, bounded rationality and decentralized decision-making further increase coordination difficulty. Information asymmetry and moral hazard may jointly reduce system efficiency and profitability [8,9].

Although previous studies have generated substantial results in supply chain optimization, moral hazard management, and capacity planning, these issues are often examined separately. Limited research has explored their interactions in service supply chains. In particular, the dynamic relationship between moral hazard and additional capacity decisions remains unclear. To address this gap, this study develops an SSC optimization model that integrates moral hazard and additional capacity decisions. The proposed model investigates the interaction mechanisms between these two factors and explores collaborative strategies under information asymmetry and demand uncertainty. The findings can provide theoretical support for more resilient and sustainable decision-making in complex service environments.

# 2 Model Description and Basic Assumptions

## 2.1 Model Description

A service supply chain is a complex system composed of multiple independent decision-making entities. Each participant aims to maximize its own profit. Due to bounded rationality and information asymmetry, opportunistic behaviors may occur among supply chain members. Specifically, suppliers may intentionally reduce service quality to obtain additional profits. In response, integrators impose quality monitoring and penalty mechanisms to constrain such behaviors. Therefore, the interactions between suppliers and integrators form a dynamic game relationship.

Within the supply chain power structure, the service integrator plays a dominant role. It coordinates profit allocation and monitoring strategies through a centralized decision-making mechanism. However, the operation of service supply chains faces various sources of uncertainty. Demand fluctuations may result in either excess capacity or capacity shortages. In highly competitive markets, decision errors made by a single participant may generate system-wide impacts on the entire supply chain.

Under traditional decentralized decision-making, conflicts in objectives and strategic competition among firms may arise. In contrast, centralized decision-making adopts a unified decision framework and coordinated profit allocation principles. This approach can effectively reduce conflicts among supply chain members and improve overall system performance.

It should also be noted that centralized decision-making can only partially mitigate demand uncertainty. As a demand-driven supply chain, capacity planning still relies heavily on demand forecasting. When actual demand exceeds regular capacity, suppliers need to establish flexible capacity mechanisms to respond to unexpected demand changes.

Therefore, this study develops a service supply chain model under a centralized decision-making framework. The proposed model focuses on the collaborative mechanism between suppliers' flexible capacity allocation and integrators' quality monitoring strategies. This mechanism aims to jointly address demand uncertainty and moral hazard, thereby improving the resilience of the entire supply chain system.

## 2.2 Assumptions

Assumption 1. For analytical simplicity and due to time limitations, the service supply chain considered in this study consists of one service supplier, one service integrator, and multiple customers.

Assumption 2. The supplier provides specific services to customers, while the integrator coordinates supplier resources and collects service payments from customers.

Assumption 3. Market demand depends only on the supplier's effort level, while other factors remain unchanged. For a given effort level, each customer receiving the service generates a fixed revenue for the integrator.

Assumption 4. No physical products are transferred in the service supply chain. Customers receive services from the supplier and generate revenue for the integrator. The supplier receives compensation from the integrator through transfer payments. Specifically, the integrator pays a fixed compensation and shares a proportion of profits with the supplier.

Assumption 5. The supplier has a limited regular capacity. Excessive capacity investment may lead to additional costs. Therefore, the supplier establishes additional capacity, such as overtime arrangements, to cope with demand uncertainty.

Assumption 6. Since services are instantaneous and non-storable, unused service capacity does not generate any revenue.

### 2.3 Parameter Settings

The model parameters are defined as follows.

(1) $\pi$ :customer payment to the integrator. $\pi(e) = ke - b$ . b denotes the cost incurred when no effort is exerted (e=0).

(2) f :provider's cost, $f(e) = ce^2 / 2$ .c denotes effort cost coefficient.

(3) x: probability of non-opportunistic behavior. If the supplier behaves opportunistically and the integrator does not monitor service quality, the supplier obtains an additional payoff T. If the integrator conducts monitoring, the supplier incurs a penalty N.

(4) y: probability of monitoring supplier service quality; d: monitoring cost of the integrator.

(5) w: fixed payment from integrator to supplier; r: profit-sharing ratio.

(6) D: customer demand. $D \in [M, N]$. $0 < M < N < \infty$ .

(7) R: regular capacity of the supplier; $\delta$ : additional capacity.

(8) h: unit cost of regular capacity; gh: unit cost of additional capacity, where g>1.

(9) m : penalty cost.

(10) p: unit revenue of the integrator from customers.

## 3 Model Description and Basic Assumptions

The service integrator and supplier interact through a mixed-strategy Nash game under a centralized decision-making framework. Both players choose strategies simultaneously. The supplier decides whether to engage in opportunistic behavior, while the integrator determines whether to conduct monitoring. The equilibrium solution is obtained by equating the expected payoffs of different strategies.

### 3.1 Model Formulation

This model considers both service quality and service capacity. Service quality depends on the supplier's opportunistic behavior and the integrator's monitoring effort. Service capacity is determined by the supplier's additional capacity investment. The model includes four scenarios: (1) non-opportunistic behavior without monitoring, (2) non-opportunistic behavior with monitoring, (3) opportunistic behavior with monitoring, and (4) opportunistic behavior without monitoring. Therefore, the expected profits of the integrator and supplier are expressed as

$$\begin{aligned} Y(x,y,\delta) &= x(1-y)\left\{\min(D,\delta+R)\bullet\pi(e_1) - w - m\left[(\delta+R)-D\right]^+\right\}(1-r) \\ &+xy\left\{\min(D,\delta+R)\bullet\pi(e_1) - w - m\left[(\delta+R)-D\right]^+\right\}(1-r) - dxy \\ &+(1-x)y\left\{\min(D,\delta+R)\bullet\pi(e_2) - w - m\left[(\delta+R)-D\right]^+\right\}(1-r) - (d-N)(1-x)y \\ &+(1-x)(1-y)\left\{\min(D,\delta+R)\bullet\pi(e_2) - w - m\left[(\delta+R)-D\right]^+\right\}(1-r) \end{aligned} \tag{1}$$

$$\begin{aligned} Z(x,y,\delta) &= x(1-y)\left\{\left[\min(D,\delta+R)\bullet\pi(e_1) - w - m\left[(\delta+R)-D\right]^+\right]r - f(e_1)(R+g\delta) + w\right\} \\ &+xy\left\{\left[\min(D,\delta+R)\bullet\pi(e_1) - w - m\left[(\delta+R)-D\right]^+\right]r - f(e_1)(R+g\delta) + w\right\} \\ &+(1-x)y\left\{\left[\min(D,\delta+R)\bullet\pi(e_2) - w - m\left[(\delta+R)-D\right]^+\right]r - f(e_2)(R+g\delta) + w - N + T\right\} \\ &+(1-x)(1-y)\left\{\left[\min(D,\delta+R)\bullet\pi(e_2) - w - m\left[(\delta+R)-D\right]^+\right]r - f(e_2)(R+g\delta) + w + T\right\} \end{aligned} \tag{2}$$

The expected profit of the service supply chain is

$$\begin{aligned} G(x,y,\delta) &= x(1-y)\left\{\min(D,\delta+R)\bullet\pi(e_1) - w - m\left[(\delta+R)-D\right]^+ - f(e_1)(R+g\delta) + w\right\} \\ &+xy\left\{\min(D,\delta+R)\bullet\pi(e_1) - w - m\left[(\delta+R)-D\right]^+ - f(e_1)(R+g\delta) + w - d\right\} \\ &+(1-x)y\left\{\min(D,\delta+R)\bullet\pi(e_2) - w - m\left[(\delta+R)-D\right]^+ - f(e_2)(R+g\delta) + w - N + T - d\right\} \\ &+(1-x)(1-y)\left\{\min(D,\delta+R)\bullet\pi(e_2) - w - m\left[(\delta+R)-D\right]^+ - f(e_2)(R+g\delta) + w + T\right\} \end{aligned} \tag{3}$$

Taking the partial derivative of Eq. (1) with respect to y and Eq. (2) with respect to x, the mixed-strategy Nash equilibrium is derived.

$$\left(x^*, y^*\right) = \left(\frac{N-d}{N}, \frac{\min(D,\delta+R)\bullet rk(e_2-e_1) + \frac{c}{2}(R+g\delta)\left(e_1^2-e_2^2\right) + T}{N}\right) \tag{4}$$

Since

$$\begin{aligned} \frac{\partial G(x,y,\delta)}{\partial\delta} &= x\bullet F(\delta+R)(ke_1-b) + (1-x)\bullet F(\delta+R)(ke_2-b) - m \\ &+m\bullet F(\delta+R) - \frac{cx}{2}e_1^2 g - \frac{c(1-x)}{2}e_2^2 g \end{aligned} \tag{5}$$

$$\frac{\partial^2 G(x,y,\delta)}{\partial\delta^2} = -m\bullet f(\delta+R) < 0 \tag{6}$$

An optimal level of additional capacity exists that maximizes the total profit of the service supply chain.

$$\delta^* = F^{-1}[\frac{cxe_1^2g\text{-}c(1\text{-}x)e_2^2g\text{+}2m}{2(xke_1\text{-}xke_2\text{+}ke_2\text{-}b + m)}]\text{-}R \tag{7}$$

Based on the analysis of the service supply chain model, the following results are obtained:

(1) Whether the supplier engages in deceptive or opportunistic behavior depends on the penalty cost imposed on the supplier and the monitoring cost of the integrator.

(2) The probability that the integrator chooses to monitor is not only related to r, but also affected by k, e, c, T, N, D, R, G and $\delta$. $dy^* / dD > 0$ indicates that as customer demand increases, the probability of monitoring increases. To retain customers, the integrator must ensure satisfactory service quality. Therefore, to prevent suppliers from engaging in opportunistic behavior, the integrator increases the monitoring probability. $dy^* / dR > 0$ shows that an increase in regular capacity leads to a higher probability of monitoring. As normal capacity increases, supplier cost rises. Opportunistic behavior can generate extra profit to offset this cost. Anticipating this, the integrator increases monitoring. $dy^* / dg < 0$ suggests that as the unit cost coefficient of additional capacity increases, the probability of monitoring decreases. Higher additional capacity cost increases supplier investment. The integrator expects better service and reduces monitoring. $dy^* / d\delta < 0$ indicates that an increase in additional capacity leads to a lower probability of monitoring. In SSCs, capacity is demand-driven. Higher additional capacity reflects higher demand and satisfactory service, so the integrator reduces monitoring.

(3) The unit revenue and the supplier's regular capacity cost are determined by the supplier's effort level.

## 4 Numerical Analysis

Consider a service supply chain consisting of one service supplier, one service integrator, and customers. Let A denote the service supplier and B denote the service integrator. The supplier receives a fixed payment of 1000 from the integrator. The integrator then shares 70% of the remaining total profit with the supplier.

If the supplier reduces service quality, it obtains an additional profit of 1000. In this case, if the integrator detects such opportunistic behavior, a penalty of 6000 is imposed on the supplier. The monitoring cost of the integrator is 3000.

The sensitivity coefficient of service effort for the integrator is 1.4, and the effort cost coefficient of the supplier is 0.04. When the supplier does not engage in opportunistic behavior, the service effort level is 40. When the supplier behaves opportunistically, the service effort level decreases to 30. If the supplier exerts no effort, it causes a loss of 5 to the integrator.

The supplier' s normal capacity is 200, and the unit cost coefficient of additional capacity is 1.2. The unit penalty cost is 20. Customer demand follows a uniform distribution with mean 300. $D \sim U[M, N], f(D) = \begin{cases} \dfrac{1}{N-M}, M \le D \le N \\ 0, otherwise \end{cases}$.

Based on Eqs. (4) and (7), the following results can be derived: $x = 0.5, y = 0.135$, $\delta^* = 43.75$. As shown in Figure 1, the service supply chain achieves a maximum profit of 6901.

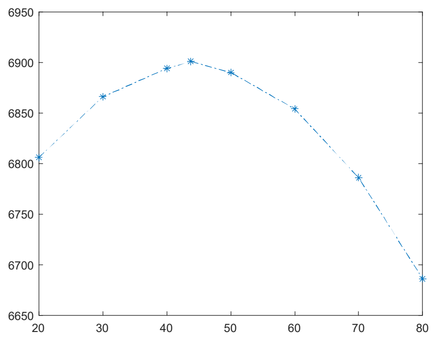


**Fig. 1.** Profit Variation of the Service Supply Chain under Nash Equilibrium

Therefore, the service supply chain achieves maximum profit when the additional capacity is set to 43.75. At the Nash equilibrium, the supplier's probability of opportunistic behavior is 0.5, and the integrator's monitoring probability is 0.135. Under this condition, the system reaches a stable state with maximum profit.

## 5 Conclusion

This study investigates service supply chain optimization by jointly considering moral hazard and additional capacity decisions under demand uncertainty. A service supply chain model involving a service supplier and a service integrator is developed within a centralized decision-making framework. To mitigate opportunistic behaviors caused by information asymmetry, the integrator adopts quality monitoring and penalty mechanisms, while the supplier establishes additional capacity to improve responsiveness under uncertain demand conditions. A mixed-strategy Nash equilibrium approach is employed to analyze the strategic interactions between both parties.

The analytical and numerical results provide several important findings. First, moral hazard behavior and monitoring strategies jointly determine the equilibrium decisions of the service supply chain. Appropriate monitoring and penalty mechanisms can effectively restrain opportunistic behaviors and improve system performance. Second, additional capacity investment plays an important role in coping with demand uncertainty and enhancing supply chain resilience. The results indicate that there exists an optimal level of additional capacity that maximizes total system profit rather than continuously increasing capacity investment. Third, the numerical analysis shows that parameters such as monitoring cost, penalty intensity, profit-sharing ratio, and additional capacity cost significantly affect equilibrium decisions and overall profitability.

From a managerial perspective, the findings suggest that service enterprises should coordinate quality governance and capacity planning decisions rather than treating them independently. Integrators can improve supply chain performance by designing appropriate monitoring mechanisms and incentive contracts, while suppliers can enhance operational flexibility through proper capacity allocation strategies.

Several limitations of this study should be acknowledged. First, the proposed model considers only a single supplier and a single integrator, whereas practical service supply chains often involve multiple participants. Second, customer demand is assumed to be independent of service quality perception, while actual market demand may be influenced by customer experience and service quality. Third, customer demand is assumed to follow a uniform distribution, which may not fully capture real-world demand patterns. Future studies can extend the model by considering multi-agent service supply chains, quality-dependent demand functions, and more general demand distributions.

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