Research on Optimization Simulation of Information Transmission Performance in Complex Service Supply Chain--Taking a Complex Agent Project as an Example

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Abstract: Complex service supply chain usually has a large amount of information stagnation, which is due to the complex information structure. This has greatly increased the pressure on the core departments of the service supply chain. Information transmission performance affects the operation effect of service supply chain and directly restricts the realization of service supply chain objectives. Taking a complex agent construction project as an example, a simulation model of information transmission in complex service supply chain is established, and the law of information transmission in complex supply chain is discussed. Through case simulation analysis, it is found that there are a series of factors affecting the performance of information transmission in complex service supply chain. Among them, information acceptance rate and information stock adjustment time are sensitive parameters of information transmission performance. The research results provide a method to optimize the performance of information transmission in complex service supply chain by adjusting parameters reasonably according to different projects in practice. This method can control the pressure of information retention in complex service supply chain beforehand, adjust the information management strategy in time, and form a good mechanism of information pre-processing.

1. Introduction

Service supply chain has the same characteristics as product supply chain. Its typical structure is "Service Provider - Service Integrator - Customer". Many studies about supply chain are not limited to purchasing, manufacturing, sales and other delivery process industries. It extends to the perspective of service supply chain, and provides research ideas for many scholars in other fields. For example, Thakur (2016) reviews the transition from the product supply chain management to the service supply chain management [1], and Apte (2016) explores the service supply chain management of the U.S. Department of Defense [2]. Especially as a specialized service, the project management process can be described by the service supply chain. Parrod (2007) analyzed the influence of cooperation degree between project agents on agent behavior for service supply chain

[3], and Jin (2008) studied the construction supply chain management system based Multi-Agent to describe the relationship between the participants in the construction project [4]. On this basis, some scholars use the service supply chain to explain the project agent system. For example, Xiao (2011) analyzed the characteristics and modes of the project agent system, and established the service supply chain structure model [5].

The service supply chain regards project task information as invisible products, and regards task "information entry, information transfer and information output" as "product production, product processing and product sale", thus describing the information transmission process of service supply chain. Information transmission is the basis of service supply chain and the driving element of project planning, organization, coordination and control in service supply chain. The information transmission network of supply chain is a dynamic structure, which reflects the conditions of service supply chain projects and the strategies of the participants. The complex service supply chains usually have a multi-level and multi-span chain structure with complex cross-cutting characteristics. As a result, the complex service supply chain has higher risk of information detention, followed by higher information management costs and stronger project operating load. The information transmission blockage has become an important factor affecting the progress of complex service supply chain projects. In view of this situation, this paper focuses on the problem of information stagnation widely existing in complex service supply chain, takes a complex service supply chain project as an example to carry out simulation analysis, and studies the method of using system dynamics simulation to optimize the performance of information transmission in complex supply chain. This method provides some references for the study of information transmission in complex service supply chain. At the same time, this method can further improve the information management strategy, reduce the cost of information management in complex service supply chain, and reduce the operation load of the service system brought by the massive information in complex service supply chain.

2. Theoretical Basis

Information transmission is one of the core of service supply chain management. Efficient information transmission can bring high performance of service supply chain management. Marinagia (2015) analyzed the relationship between information and supply chain [6]. He believed that the information coordination performance among the supply chain partners was very important, which directly affected the reliability of service supply chain operation. Lotfi (2013) believes that information management can improve the efficiency of supply chain management, ensure coordination and cooperation within the supply chain, and improve organizational performance [7]. The above research shows that the effect of information transmission among members of service supply chain system plays an important role in the efficiency of service supply chain management. Kocoglu (2011) analyzed the information transfer structure, data objects and information flow model in the supply chain, and confirmed the above role [8]. It can be seen that efficient information transmission can make the operation of service supply chain more flexible.

In the complex service supply chain, the information transmission network may be more complex. Pedro (2015) established an information transfer network model to analyze the evolution of information flow in complex service supply chain [9]. Man (2013) modeled the information flow of complex service supply chain and discussed the integrated management of information transmission and sharing [10]. He analyzed information communication in progress of the project. Durugboa (2013) used mathematical analysis to describe complex information transfer processes [11]. This method enables supply chain managers to clearly grasp the information transmission process and reduce information blockage. Misra (2010) proposes that effective flow of supply chain information can drive the operation of supply chain system [12]. It can be seen that effective information transmission provides necessary support for the operation of service supply chain. Solving information blockage, information loss and information evolution are the key points of service supply chain management.

It is an effective research method to use simulation modeling to analyze the information transmission mechanism of service supply chain. Trkman (2006) used simulation modeling to simulate the information transfer process in the supply chain, in order to study the impact of efficient information transfer on the supply chain [13]. Feng (2012) discussed the supply chain information transfer model with the method of system dynamics, and compared the results of the model under different parameters [14]. The simulation modelling method can provide decision-making basis for supply chain managers. In this paper, the system dynamics method is also used to establish the simulation model. This paper takes a complex agent project as an example to describe the information transmission structure of complex service supply chain. The purpose is to reveal the relationship among the information detention, adjustment time of information stock, and information receiving rate.

3. Research Design

3.1. Information Transmission Structure

This paper chooses a complex agent project as a case study. The participants of the agent system establish contact with each other through instruction information, funds information, and contract information, etc. In the cases selected in this paper, the participants are very diverse. The operation of this service supply chain is constrained by more constraints. Especially, the characteristics of multi-party management are obvious. This forms a more complex information transmission network, as shown in Figure 1.

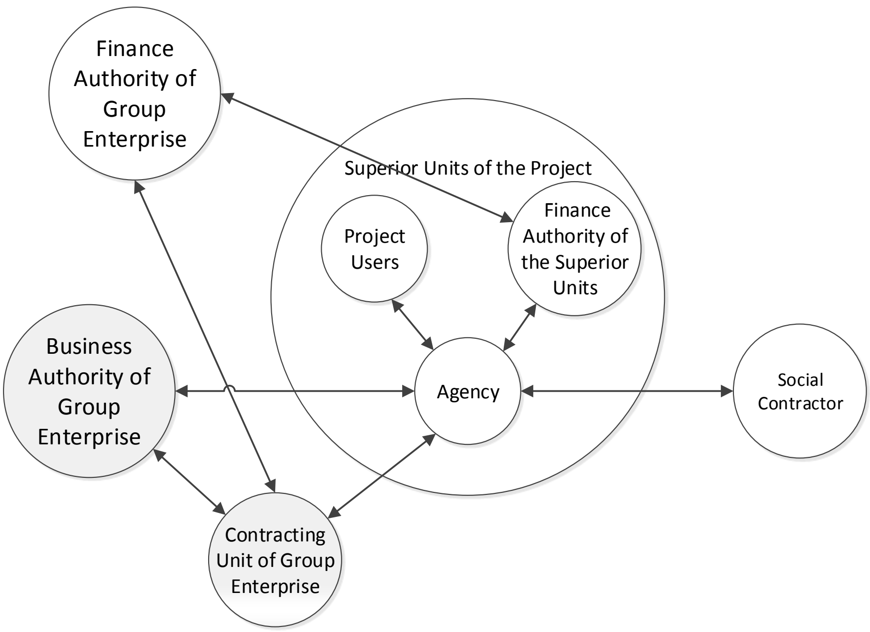


Figure 1: Information relational structure of a complex agent project.

Through statistical analysis of agent projects in 2017 and 2018, it is found that: ① Different projects have different average information transfer time, expected reserve duration, average information moving rate and average information reserve rate. ② For the same task, the adjustment time of information stock and the information receiving rate will affect the information retention time. ③ In the process of information transmission, the rate of information entry and the rate of information outflow will greatly affect the effect of information processing.

There are two forms of information flow in service supply chain. One is line information flow, which expresses the overall flow of information; the other is feature information flow, which expresses the transmission characteristics of information. The service supply chain is a network chain structure, and information flow is bidirectional. In view of the complexity of information transmission in service supply chain, this paper only discusses one-way information flow.

3.2. Model Condition

According to the information transmission of the service supply chain in the agent project, the following model conditions are proposed:

The information transfer rate is determined by the information receiving rate and the information receiving ratio. The logical calculation process is as follows: *Information transfer rate = Information receiving rate * Information receiving ratio*. The information transfer rate is a variable, which adopts the "arrival" mechanism and takes the "information receiving rate" of the other party as the criterion. That is, when the information arrives at the other party, the party has the ability to receive it, which can be regarded as the success of information transmission. Reflected in reality, the task information is sequential, and the latter task information cannot be processed if the previous task information cannot be processed. The information reception ratio is a constant. The arrival information does not necessarily all form the transmission function. There may be some subjective and objective circumstances which make the information deviate to a certain extent. The ideal state of information reception ratio is 100%.

The information receiving rate is determined by three variables, the predicted transmission amount of information received, the expected self-storage amount of information and the existing stock of information. It is also affected by the time parameter of information stock adjustment. The logical calculation process is as follows: *Amount of information receiving predictive transfer = Average information transfer rate * Average information receiving transfer time*; *Expected Information stock = Average information reserve rate * Expected information reserve duration*. These are constants: average information transmission rate, average transmission time of information receiving, average reserve ratio of information and expected information reserve duration. Their values vary according to the actual situation.

When information enters the service supply chain, it has an initial rate, and when information flows out of the service supply chain, it has a processing rate. The logical calculation process is as follows: *Information initial entry rate = Information outflow processing rate*. They are all constants and are valued according to the urgency of the task.

According to the above conditions, the following equations can be obtained:

$$v_1 = \frac{v_d \cdot t_{d1} + v_b \cdot t_{b1} - I_0}{t_T} \cdot k + v_0 \qquad (1)$$

$$v_2 = \frac{v_d \cdot t_{d2} + v_b \cdot t_{b2} - I_1}{t_T} \cdot k \qquad (2)$$

$$v_3 = \frac{v_d \cdot t_{d3} + v_b \cdot t_{b3} - I_2}{t_T} \cdot k \qquad (3)$$

$$v_4 = \frac{v_d \cdot t_{d4} + v_b \cdot t_{b4} - I_3}{t_T} \cdot k \qquad (4)$$

$$v_5 = v_x \qquad (5)$$

Among them, v_0 stands for the *Information initial entry rate*; v_1 stands for the *Information generation rate*; v_2 stands for the *Information transmission rate of higher authorities*; v_3 stands for the *Information transfer rate of agency*; v_4 stands for the *Information transfer rate of participants*; v_5 stands for the *Information Transfer Rate of Contractors*; v_x stands for the *Information outflow processing rate*; v_d stands for the *Average information transfer rate*; v_b stands for the *Average information reserve rate*; t_T stands for the *Information stock adjustment time*; k stands for the *Information receiving ratio*; t_{d1} stands for the *Information receiving transferring time of higher authorities*; t_{b1} stands for the *Information expected reserve time of higher authorities*; t_{d2} stands for the *Information receiving transferring time of agency*; t_{b2} stands for the *Information expected reserve time of agency*; t_{d3} stands for the *Information receiving transferring time of participants*; t_{b3} stands for the *Information expected reserve time of participants*; t_{d4} stands for the *Information expected reserve time of contractors*; t_{b4} stands for the *Information expected reserve time of contractors*; I_0 stands for the *Information stock of higher authorities*; I_1 stands for the *Information stock of agency*; I_2 stands for the *Information stock of participants*; I_3 stands for the *Information stock of contractors*.

According to the relationship among variables, there are the following equations:

$$\frac{dI_0}{dt} = v_1 - v_2 \quad (6)$$

$$\frac{dI_1}{dt} = v_2 - v_3 \quad (7)$$

$$\frac{dI_2}{dt} = v_3 - v_4 \quad (8)$$

$$\frac{dI_3}{dt} = v_4 - v_5 \quad (9)$$

4. Simulation Analysis and Discovery

4.1. Simulation Experiment

The system dynamics model is established by using Anylogic software. Eight groups of experiments were conducted. The parameters of the simulation experiment are set according to the actual situation of the agent project, as shown in Table 1. According to the schedule of the agent project, the duration of the experiment was set to 672 hours. At 120 hours of all experiments, the information transmitted from the higher authorities to the system stopped. The information outflow processing rate is determined according to the degree of information retention in the model. ① When the model runs for 300 hours, the information outflow processing rate is adjusted to 15 (initial value is 10). ② When the model runs for 300 hours, the information outflow processing rate is adjusted to 15 (initial value is 10); when the model runs for 600 hours, the information outflow processing rate is adjusted to 20. ③ When the model runs for 300 hours, the information outflow processing rate is adjusted to 20(initial value is 10). ④ No adjustment measures will be taken.

Table 1: Initial parameter settings.

Parameter	Initial settings	Parameter	Initial settings
Average information reserve rate	6/h	*Information expected reserve time of contractors*	24h
Average information transfer rate	10/h	*Information expected reserve time of higher authorities*	48h
Information receiving transferring time of higher authorities	24h	*Information expected reserve time of agency*	72h

Information receiving transferring time of agency	48h	*Information expected reserve time of participants*	36h
Information receiving transferring time of participants	36h	*Information expected reserve time of contractors*	24h

Eight groups of experiments were conducted. According to the operation of the model, we can judge whether to take adjustment measures at any time. The parameters and conditions of all experiments are shown in Table 2.

4.2. Comparative Analysis

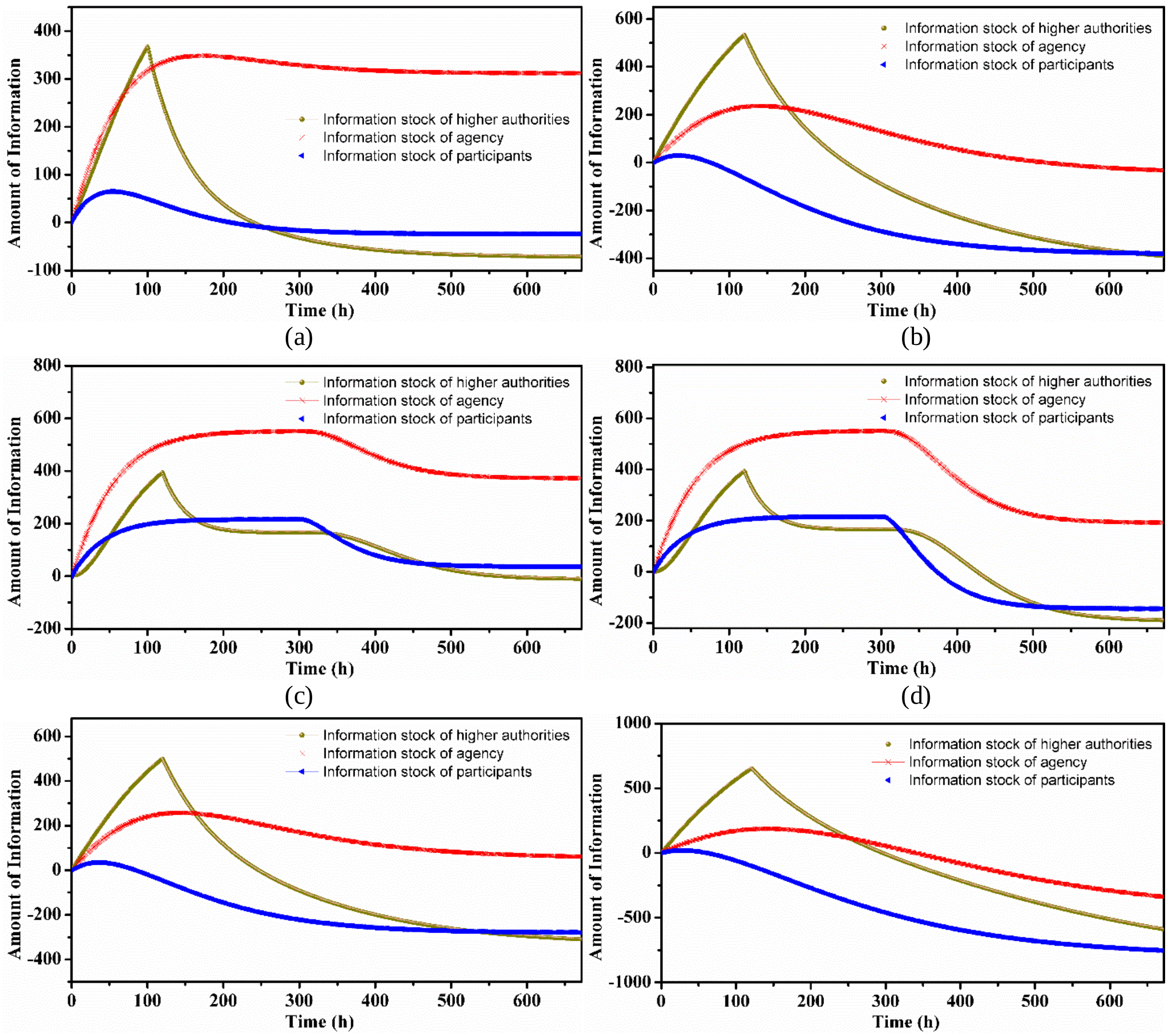
Through experiments, it is found that the information stock of agency is the primary factor of information retention. Figure 2 shows the change of information retention pressure of agency in eight cases. When the information stock adjustment time is 96 hours, the information retention of agency will not affect the operation of the system (such as Experiment 2 and Experiment 6). When the information stock adjustment time is 60 hours, if the information receiving ratio is 0.7, the information detention of the system will not occur (such as Experiment 5); if the information receiving ratio is 1, the measure should be taken to control information retention (such as Experiment 1). When the information stock adjustment time is 36 hours, if the information receiving ratio is 1, the information retention pressure of the agency is relatively high. The degree of mitigation is limited after the adoption of measures (such as Experiment 3 and Experiment 4); if the information receiving ratio is 0.7, the information retention pressure of the agency is very high, the relevant measures are not enough to alleviate the pressure of information retention (such as Experiment 7 and Experiment 8). A separated examination of the time polygraph of the agency can make a better comparison, as shown in Figure 3.

Table 2: Parameters and conditions for experiments.

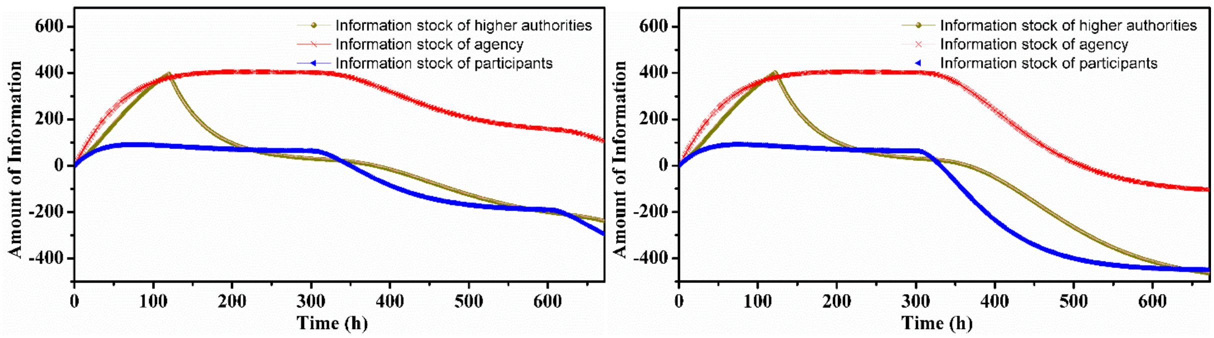
experiment	settings	experiment	settings
Experiment 1 Figure 2 (a)	*Information receiving ratio*=1 *Information Stock Adjustment Time*=60 Adjustment Conditions=①	Experiment 5 Figure 2 (e)	*Information receiving ratio*=0.7 *Information Stock Adjustment Time*=60 Adjustment Conditions=④
Experiment 2 Figure 2 (b)	*Information receiving ratio*=1 *Information Stock Adjustment Time*=96 Adjustment Conditions=④	Experiment 6 Figure 2 (f)	*Information receiving ratio*=0.7 *Information Stock Adjustment Time*=96 Adjustment Conditions=④
Experiment 3 Figure 2 (c)	*Information receiving ratio*=1 *Information Stock Adjustment Time*=36 Adjustment Conditions=②	Experiment 7 Figure 2 (g)	*Information receiving ratio*=0.7 *Information Stock Adjustment Time*=36 Adjustment Conditions=②
Experiment 4 Figure 2 (d)	*Information receiving ratio*=1 *Information Stock Adjustment Time*=36 Adjustment Conditions=③	Experiment 8 Figure 2 (h)	*Information receiving ratio*=0.7 *Information Stock Adjustment Time*=36 Adjustment Conditions=③

5. Conclusion

Through the simulation experiment, the information transmission operation of complex service supply chain can be quickly and intuitively displayed. In this paper, a case of complex service supply chain is selected to test, which proves that this method can pre-control the change of information retention pressure in complex service supply chain. This enables managers to adjust their coping strategies in a timely manner. It has positive significance to reduce the management cost and operation load of complex service supply chain. Due to the complexity of the information transfer structure and the enormity of the model in the complex service supply chain, this paper only establishes the basic model based on the information detention time. This model focuses on the one-way flow of a single information flow to reveal the characteristics of information transmission structure in complex service supply chain. In the follow-up study, we will continue to explore multiple information flows in the complex service supply chain, and consider the two-way flow of information. At the same time, we will also analyze the key nodes of information detention in complex service supply chain, and then consider the uniqueness of information transmission.



(a) (b) (c) (d) (e) (f)



(g) (h)

Figure 2: Time polygraph of experiments.

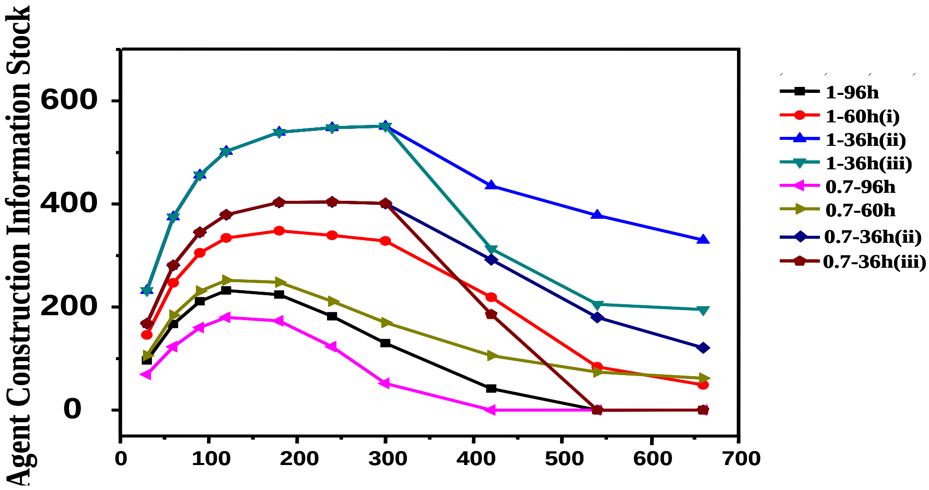


Figure 3: Time polygraph of agency.

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