Reliability of Automobile Logistics Service Supply Chain

Meiling He [a], Peng Jing [b]

School of Automotive and Traffic Engineering, Jiangsu University, Zhenjiang 212013, China

[a]hemeiling@ujs.edu.cn, [b]jingpeng@ujs.edu.cn

Abstract. Considering the uncertainty characteristic of automobile Logistics Service Supply Chain (LSSC), the paper researches its reliability. The automobile LSSC usually includes Functional Logistics Service Provider (FLSP), automobile Logistics Service Integrator (LSI) and Logistics Service Demander (LSD). Based on Markov process, the general model for automobile LSSC is established. Then the transition probability between different states is discussed. Last, the steady state availability of automobile LSSC can be got.

Keywords: Automobile, Logistics Service Supply Chain (LSSC), reliability.

1. Introduction

Automobile LSSC is a new type of service supply chain. In the process of operation, it faces stochastic demand. Some mathematical programming models are developed to determine the optimal adjustment decisions regarding production reallocation among plants under different fluctuating demands [1, 2]. Literature [3] proposes a mechanism for deriving a fair price for trading reliability targets between suppliers using information gained about potential failure modes through development and the costs of activities required to generate such information. Literature [4] presents a statistical methodology to construct a model for early detection of reliability problems using information from warranty databases and upstream supply chain. Logistics and supply chain disruptions hinder the availability of cost-effective solutions, however industry infrastructure will adapt to follow market acceptance [5]. Understanding and resolution of reliability issues will prove a critical step that evolution.

2. Structure of Automobile LSSC

Automobile logistics includes parts logistics, vehicle logistics and after-sales service logistics. Automobile LSSC penetrates the above processes. According to the structure of supply chain, automobile LSSC are composed of FLSP, automobile LSI and LSD [6], as shown in Fig. 1.

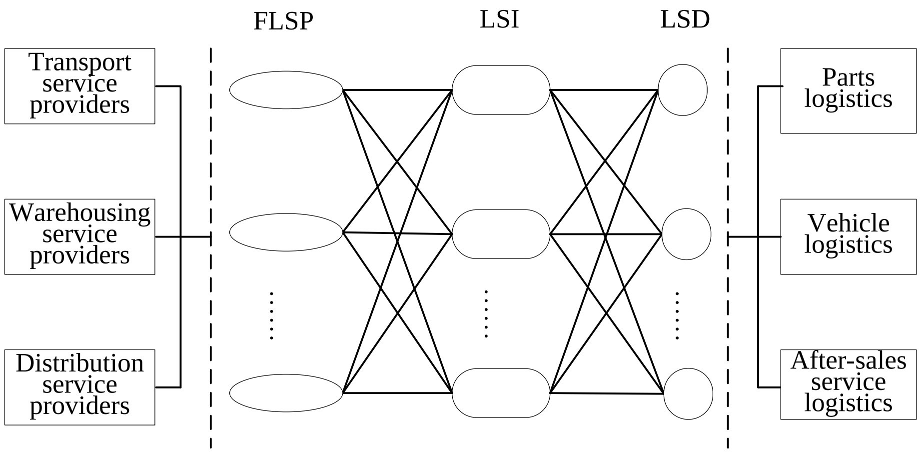

Fig.1 The structure of automobile LSSC

The core task of automoble LSSC is purchasing the logistics service. In the process of its operation, the automobile LSI is in the core position. It doesn't have logistics resources or for a small proportion. It relies on its strong ability of management and integration, purchasing logistics capability from FLSP and integrating, to provide professional logistics services for LSD.

3. Reliability Analysis

3.1 Symbol Description

$\boldsymbol{A}$ transition rate matrix.
E finite state space.
W working state space.
λ failure rate.
μ repair rate.
$P_{ij}(t)$ transition probability function.
$A(t)$ instantaneous availability of automobile LSSC.
$X(t)$ the state of automobile LSSC in time *t*.
$P_i(t)$ probability in state *i* for automobile LSSC in time *t*.
$F(x)$ distribution function.
$f(x)$ probability density.
A steady state availability.

3.2 Definition and Hypothesis

Hypothesis 1: $\{X(t), t \geq 0\}$ is a stochastic process in $E = \{0,1,\cdots\}$ or $E = \{0,1,\cdots,N\}$. For Any natural number *n* and $0 \leq t_1 < t_2 < \cdots < t_n$,

$$\begin{aligned} &P\{X(t_n) = i_n | X(t_1) = i_1, X(t_2) = i_2, \cdots, X(t_{n-1}) = i_{n-1}\} \\ &\quad = P\{X(t_n) = i_n | X(t_{n-1}) = i_{n-1}\}, \\ &\quad i_1, i_2, \cdots, i_n \in E. \end{aligned} \tag{1}$$

Then $\{X(t), t \geq 0\}$ is continuous time markov process in E.

If for any $t, u \geq 0$,

$$P\{X(t+u) = j | X(u) = i\} = P_{ij}(t), \quad i, j \in E. \tag{2}$$

It has nothing to do with u. $\{X(t), t \geq 0\}$ is homogeneous.

Hypothesis 2: an automobile LSSC is composed of n series subsystems, while the failure rate of i subsystem is λ_i and the repair rate is μ_i. λ_i, μ_i >0, i =1, 2… n.

State 0: all subsystems (n) are normal;

State i : i subsystem has an accident while the others are normal, i =1, 2… n.

Theorem 1: if initial state distribution is $P_0(0), P_1(0), \cdots P_N(0)$, the instantaneous availability of automobile LSSC is

$$A(t) = \sum_{j \in W} P_j(t). \tag{3}$$

Here, $P_j(t), j \in W$ is the solution of the following equations.

$$\begin{cases} P_i'(t) = \sum_{k \in E} P_k(t) a_{ki}, \quad i \in E \\ \text{initial condition}: P_0(0), P_1(0), \cdots P_N(0) \end{cases} \tag{4}$$

Convert Eq. (4) to matric.

$$\begin{cases} \boldsymbol{P}'(t) = \boldsymbol{P}(t)\boldsymbol{A} \\ \text{initial condition}: \boldsymbol{P}(0) \end{cases} \tag{5}$$

Here, $\boldsymbol{P}(t)=(P_0(t),P_1(t),\cdots,P_N(t))$, $\boldsymbol{A}=(a_{ij})$, $\boldsymbol{P}'(t)$ means taking the derivative of each subitem.

Theorem 2: the steady state availability of automobile LSSC is

$$A=\sum_{j\in W}\pi_j . \tag{6}$$

Here, $\pi_j,\ j\in W$ satisfies the following.

$$\begin{cases}(\pi_0,\pi_1,\cdots,\pi_N)\boldsymbol{A}=(0,0,\cdots,0)\\ \pi_0+\pi_1+\cdots+\pi_N=1\end{cases} \tag{7}$$

3.3 State Transition

The automobile LSSC can be regarded as a series of several subsystems. If work time and repair time after fault of subsystems in the supply chain systems obey exponential distribution and their parameters keep unchanged, we can think of the supply chain as a Markov process.

If n subsystems are normal, the whole supply chain system is in working condition. When a subsystem has an accident, the supply chain system is at fault. Only when the fault subsystem has been repaired, the supply chain system will be in working condition once again.

Then the transition probability between different states in the time Δt can be got:

$$\begin{cases}P_{0i}(\Delta t)=\lambda_i\Delta t+o(\Delta t),\\ P_{i0}(\Delta t)=\mu_i\Delta t+o(\Delta t), i=1,2,\cdots,n\\ P_{jk}(\Delta t)=o(\Delta t), \qquad j,k\neq 0,\ j\neq k\end{cases} \tag{8}$$

The probability of changed state which happens two times or more in the time Δt is $o(\Delta t)$ .According to the equation (8), the following equation can be got.

$$\begin{cases}P_{00}(\Delta t)=1-\sum_{i=1}^{n}\lambda_i\Delta t+o(\Delta t),\\ P_{jj}(\Delta t)=1-\mu_j\Delta t+o(\Delta t), \qquad j=1,2,\cdots,n\end{cases} \tag{9}$$

The state transition diagram of the automobile LSSC in the time Δt is shown in Fig. 2.

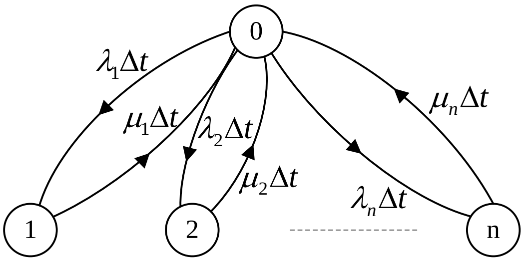

Fig.2 The state transition diagram of the automobile LSSC

Then the transfer matrix can be got.

$$A=\begin{pmatrix}-\Lambda & \lambda_1 & \lambda_2 & \cdots & \lambda_n\\ \mu_1 & -\mu_1 & 0 & \cdots & 0\\ \mu_2 & 0 & -\mu_2 & \cdots & 0\\ \cdots & \cdots & \cdots & \cdots & \cdots\\ \mu_n & 0 & 0 & \cdots & -\mu_n\end{pmatrix} \tag{10}$$

Here, $\Lambda=\sum_{i=1}^{n}\lambda_i$.

Then, the steady state availability of automobile LSSC is

$$A=(1+\sum_{i=1}^{n}\frac{\lambda_i}{\mu_i})^{-1}. \tag{11}$$

4. Conclusion

The paper studies the reliability of automobile LSSC. Firstly, it gives the normal structure of automobile LSSC. Based on reliability theory, this paper researches Markov process. Then, the instantaneous availability and the steady state availability of automobile LSSC are got. By state transition diagram, the transfer matrix is analyzed. It provides the basis for the reliability of other type LSSC.

Acknowledgements

This work was supported by China Postdoctoral Science Foundation funded project (No. 2014M551526), the Social Science Foundation of Jiangsu Province, China (No. 11SHD011), Jiangsu Planned Projects for Postdoctoral Research Funds, China (No. 1302097B) and the Senior Talents Foundation of Jiangsu University, China (Project No. 11JDG119). We thank the anonymous reviewers for their useful comments.

References

[1] C. HSU, H. LI: Reliability evaluation and adjustment of supply chain network design with demand fluctuations. International Journal of Production Economics, Vol. 132(2011) No.1, p.131-145.

[2] S.Y. SOHN, I.S. CHOI: Fuzzy QFD for supply chain management with reliability consideration. Reliability Engineering & System Safety, Vol. 72(2001) No.3, p.327-334.

[3] J. QUIGLEY, L. WALLS: Trading reliability targets within a supply chain using Shapley's value. Reliability Engineering & System Safety, Vol. 92(2007) No.10, p.1448-1457.

[4] C. ZHOU, R.B. CHINNAM, A. KOROSTELEV: Hazard rate models for early detection of reliability problems using information from warranty databases and upstream supply chain. International Journal of Production Economics, Vol. 139(2012) No.1, p.180-195.

[5] C.E. BAUER, H.J. NEUHAUS: Embedded packaging and assembly; Reliability and supply chain implications. Microelectronics Reliability, Vol. 53(2013) No.9–11, p.1179-1182.

[6] M.L. HE: Design and Coordination in Logistics Service Supply Chain Based on Reliability Analysis (Ph.D., Southwest Jiaotong University, China 2010), p.28.