International Journal of Information Systems and Supply Chain Management
Volume 15 • Issue 1 • Quarterly 2022

The Impact of Digital Twins on Local Industry Symbiosis Networks in Light of the Uncertainty Caused by the Public Crisis

Ziyue Chen, Norwegian University of Science and Technology, Norway
Lizhen Huang, Norwegian Univeristy of Science and Technology, Norway

ABSTRACT

Digital twins provide a solution for information-sharing between enterprises, thereby alleviating uncertainties in the supply chain. In light of the public crisis caused by COVID-19, the authors suggest a signal game model for a two-stage supply chain with two suppliers and two manufacturers. Based on the model, the impact of the digital twin platform on the profits of the local industrial symbiosis network is analyzed. The results show that the uncertainty of supply and demand caused by the public crisis has led to fluctuations in profits and profit volatility. Under this influence, suppliers are willing to participate in information sharing on the digital twin platform, but manufacturers are less willing to participate. Moreover, application of the digital twin platform in information sharing is conducive to maintaining and promoting the smooth operation of the industrial chain under these conditions of uncertainty.

KEYWORDS

Digital Twin, Game Theory Model, Industrial Symbiosis Network, Information Sharing, Uncertainty

INTRODUCTION

The industrial symbiosis (IS) network refers to the long-term cooperative symbiosis formed by the transfer and exchange of material, energy, knowledge, and human and technological resources between companies within a region. The network aims to obtain both environmental and competitive benefits (Wang, Mishima, & Adachi, 2021). The enterprise-level IS network and hybrid network, including IS and traditional modes of manufacturing, are newer endeavours in Norway. However, COVID-19 has caused economic turmoil worldwide since the beginning of 2020. Except for some basic industries (i.e., medical, public security, food retailing, etc.), most industries have suffered a severe shock. Thus, Norway is experiencing has its highest unemployment rate since World War II.

COVID-19 has brought uncertainty to the manufacturing industry and production process due to uncertain supplies, transportation disruption, and indeterminate demand (Shrivastava, Ernst, & Krishnamoorthy, 2019). In addition, many companies on the IS network have not established a fixed mode of information communication and transaction. When dealing with shocks like COVID-19, difficulties in information sharing and communication lead to greater challenges than faced by companies in the traditional supply chain. First, the material supply is highly uncertain. It is impossible to order recycled materials or predict their output because recycled materials are not a mainstream

DOI: 10.4018/IJISSCM.20220101

product of the suppliers. The output of recycled materials depends on the output of mainstream products (Liao & Li, 2016). Greater instability of mainstream product supply chains during COVID-19 makes their supply on the symbiosis network more unstable. Second, the costs and environmental impacts of production plans based on renewable materials must be evaluated. Availability of recycled materials is low and quality is unstable. Compared with traditional methods like landfills and incineration, the renewable remanufacturing processes may lead to unexpectedly high production costs, which cause more environmental pollution (Prosman & Sacchi, 2018). However, during COVID-19, communication between companies was restricted and could not be assessed in due time.

To solve this uncertain challenge, more information sharing between enterprises on the network is necessary (Chan, Liu, & Szeto, 2017; Kiil et al., 2019). Digital Twins (DT), as an important technology for the realization of Industry 4.0, can combine the Internet of things (IoT), artificial intelligence (AI), machine learning, and software analysis with spatial network diagrams to create real-time digital simulation models. These models are updated and changed as the physical copy changes (Zhang et al., 2019). As an emerging solution for data integration and real-time processing to realize intelligent production, the DT platforms have the advantages of real-time data transmission, data analysis, and information visualization (Qi & Tao, 2018). This provides a potential solution for information communication of enterprises on the current IS network. However, there is limited research on the impact of the DT platform on the IS networks.

The authors of this study analyse the impact of the DT-based vertical information sharing between enterprises in the local IS network under a public crisis represented by COVID-19. It aims to illustrate the economic impact of the DT platform's information-sharing function on the IS supply network. First, the authors establish a signal game model framework to describe a mixed IS network composed of two suppliers and two manufacturers. Second, based on the scenario analysis, the authors model three scenarios in which two manufacturing companies agree or disagree to share demand information with suppliers through the DT platform. Based on the solution of the models, the authors compare the consequences of these decisions and discover the influence of the platform on the amount and stability of enterprise profits.

The main contributions of this article are reflected in three aspects. First, regarding the aspect of content, current research on IS and the DT is undergoing rapid development. At present, there is little research on solutions to the information sharing of IS enterprises and application of the DT platform in interenterprise information sharing. This paper demonstrates the role of the DT information-sharing function on the IS network based on the signal game model, enriching the research content of the IS field and the DT in the cross-enterprise application field. Second, regarding the method, this paper constructs an IS network game model of two suppliers and two manufacturers. It enriches not only the research related to such models, but also the research into IS networks. Third, regarding the application, this paper increases the understanding of its application in cross-enterprise information sharing and promotes the digital transformation of IS networks.

This paper is arranged as follows. The second section, the literature review, discusses current research on issues related to information sharing in IS, the application of the DT in information sharing, and the enterprise game model in the supply chain. A supply chain model for IS is constructed in the third section, which includes four companies in the supply chain, their production relationships, and three types of information sharing models among these companies. The fourth section is a review of the results. Based on the reverse induction method, the outputs, prices, and profits of the companies in equilibrium under the information sharing modes are obtained. The fifth section provides a comparative analysis of the equilibrium solutions obtained in the fourth section and discusses the parameters in the model. The last section is the conclusion and implications.

Background

The literature related to this article includes three topics: (1) information sharing in IS; (2) application of the DT to information sharing; and (3) game models for enterprises in the supply chain. This section