Graph Database to Enhance Supply Chain Resilience for Industry 4.0

Young-Chae Hong, Ford Motor Company, USA
https://orcid.org/0000-0001-6330-6101

Jing Chen, Ford Motor Company, USA

ABSTRACT

Supply chain network in the automotive industry has complex, interconnected, multiple-depth relationships. Recently, the volume of supply chain data increases significantly with Industry 4.0. The complex relationships and massive volume of supply chain data can cause visibility and scalability issues in big data analysis and result in less responsive and fragile inventory management. The authors develop a graph data modeling framework to address the computational problem of big supply chain data analysis. In addition, this paper introduces time-to-stockout analysis for supply chain resilience and shows how to compute it through a labeled property graph model. The computational result shows that the proposed graph data model is efficient for recursive and variable-length data in supply chain, and relationship-centric graph query language is capable of handling a wide range of business questions with impressive query time.

KEYWORDS

Big Data, Graph Database, Industry 4.0, Risk Management, Supply Chain Resilience

INTRODUCTION

Globalization have stimulated automotive industry to develop globally interconnected and complex supply chain networks with greater physical distances. Henry Ford's supply chain was integrated and conceptually simple at the beginning of the twentieth century (The Economist, 2009). However, by the modern globalized economy, Ford accepted that they could not be the best in every field and began to develop interconnected and complex structures like *supply web* than supply chain (CSCMP's Supply Chain Quarterly, 2010). Thus, supply chain distribution risks increase with number of involved organizations in the network (Raghunath K. M., 2018). Supply chain data relationships become interconnected, and multi-tier rather than hierarchical or one-to-one. As the volume and complexity of data grow, supply chain managers require greater data transparency to analyze complex network behaviors to understand and support strategic decision makings. To achieve this, automotive industry companies need to digitize their supply chains to visualize better and understand how they work. However, due to its rapidly growing size and complexity of data, few companies have been able to apply

DOI: 10.4018/IJISSCM.2022010104

big analytics techniques to manage their supply chains. We developed a graph database framework to integrate multiple complex levels within an automotive supply chain network to enhance supply chain transparency.

One of the significant challenges for supply chain management is to mitigate risk by creating resilient supply chains. The literature has produced many definitions of supply chain resilience by several disciplines. Resilient supply chains require strong traceability systems for effective and timely decision making for external and internal changes. However, a recent survey shows that most supply chain companies still rely on spreadsheets to plan their supply chain process, making them less responsive and fragile (Supply Chain 247, 2018; Reuters Events, 2018). Recent advances in *big analytics* and AI support fast and effective decisions in many areas. In this paper, we evaluate one of the advanced databases in big data for supply chain management by testing its computational performance for big data analysis. Especially, we design a supply chain data model for graph database which tracks all the flow of raw materials from tier suppliers to finished products and their holistic interrelationships. Also, we introduce Time-to-Stockout analysis for supply chain resilience. The proposed Time-to-Stockout (TTS) performance metric could simplify the dynamic nature of the supply chain environment with respect to both market-side demand and supply-side inventory. It will offer a deeper knowledge of resilience and provide tools for managers to track and monitor the inventory risk, which can be propagated through supply chains. Several previous papers have evaluated graph databases and developed benchmarks. However, most of them used synthetic data or social network data. A few recent papers start to use real data to evaluate graph databases. As far as we know, this is the first paper to use a graph database for supply chain data. Especially, we evaluate it based on real data of Ford supply chain.

The remainder of the paper consists of five other sections. First, we introduce literature papers for the supply chain and graph database. Second, we present a way to model interconnected, multiple-depth supply chain data with a graph database. Third, we suggest the Time-to-Stockout performance metric and introduce the concept of Time-to-Stockout analysis. Fourth, we show the computational results obtained by applying a graph database to Ford supply chain data, and how do we support decisions for supply chain managers. Finally, we present conclusions and discussion.

LITERATURE REVIEW

Supply Chain Resilience

As globalization developed, supply chain resilience is currently an increasing concern since the supply chain is subject to diverse types of disruptions (Liao, Bayazit, & Wang, 2014; Ribeiro & Barbosa-Povoa, 2018). Today there are many definitions of supply chain resilience proposed by different authors in the operational management area (Pereira & Da Silva, 2015). Saenz et al. (2015) listed several definitions from 67 peer-reviewed articles from 2003 to 2013 on an emerging area of supply chain research. Even recent studies (Abidi, Bandyopadhayay, & Gupta, 2017; Lotfi, Mehrjerdi, Pishvaee, Sadeghieh, & Weber, 2019; Zare Mehrjerdi & Lotfi, 2019; Guoyi, Caiquan, Yubin, & Yunhui, 2020) suggest a sustainable and resilient closed-loop supply chain network. Briefly, resilient supply chains incorporate event readiness, are capable of providing an efficient response, and often are capable of recovering to their original state or even better post the disruptive event (Ponomarov & Holcomb, 2009). Therefore, a resilient supply chain needs to balance risk and costs to prevent or recover quickly from a multitude of dynamic and simultaneous risk-related disruptions (Deloitte, 2014).

One of key resilience factors is supply chain visibility (Ribeiro & Barbosa-Povoa, 2018). Supply chain visibility in multi-tier supply chains is characterized by traceability, mapping, and transparency. First, supply chain traceability is the ability to identify, trace and track the history, application or location of parts and products at any stage in the supply chain, as described by International Organization for Standardization (ISO) (2015). Second, supply chain mapping is a tool to show holistic

Related Content

Building Ambidextrous Supply Chains in SMEs: How to Tackle the Barriers?
Mohd. Nishat Faisaland Faisal Talib (2017). *International Journal of Information Systems and Supply Chain Management (pp. 80-100).*
www.irma-international.org/article/building-ambidextrous-supply-chains-in-smes/188655

Application of a Cold-Chain Logistics Distribution System Based on Cloud Computing and Web Delivery Date Management
Fei Tang (2023). *International Journal of Information Systems and Supply Chain Management (pp. 1-16).*
www.irma-international.org/article/application-of-a-cold-chain-logistics-distribution-system-based-on-cloud-computing-and-web-delivery-date-management/318644

The Impact of Lifestyle and Attitude Functions on Luxury Goods on Emotional Attachment Towards Luxury Brands
Mohammad Kashani, Alireza Aslani, Mohammad R. Esfidaniand Seyed Reza Seyed Javadin (2017). *International Journal of Applied Logistics (pp. 21-40).*
www.irma-international.org/article/the-impact-of-lifestyle-and-attitude-functions-on-luxury-goods-on-emotional-attachment-towards-luxury-brands/190401

The Role of Technological Development on Renewable Energy Usage: An Econometric Analysis for G7 Countries
Serhat Yüksel, Hasan Dinçerand Gülsüm Sena Uluer (2020). *Handbook of Research on Sustainable Supply Chain Management for the Global Economy (pp. 136-153).*
www.irma-international.org/chapter/the-role-of-technological-development-on-renewable-energy-usage/257467

Analysis of Design Alternatives of End-of-Life Products Under Fractional Yields
Aditi D. Joshiand Surendra M. Gupta (2018). *Handbook of Research on Supply Chain Management for Sustainable Development (pp. 18-41).*
www.irma-international.org/chapter/analysis-of-design-alternatives-of-end-of-life-products-under-fractional-yields/203957