The Application of the Internet of Things in Managing Supply Chains

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INTRODUCTION

Concept of supply chain management (SCM) was introduced in the early 1980s (Melnyk and Seftel, 2016), but its roots go back as far as business itself. Firms have been planning and scheduling production, procuring materials and services, and storing and transporting finished goods to customers for more than a century (Drake, 2012). They gradually began to recognize the interrelationships between these business functions in enabling the delivery of a product or service to satisfy customers' requirements. SCM involves the coordination of these traditional business functions both within an organization and between upstream and downstream members of the system to serve the end consumer (Mentzer et al., 2001).

The timing of the introduction of the supply chain concept was largely dependent upon the concurrent development of business enterprise and communication information systems (Drake, 2012). This technology facilitates the sharing of information and provides the visibility that is required for geographically-dispersed supply chain partners to collaborate and to engage in joint planning and decision making (Fine, 1998). Webster (1992) describes the information resources and systems as part of the glue that holds extended supply chain networks together.

Supply chain technology continued to develop rapidly after the adoption of the SCM concept and practices, enabling firms to share information, understand demand, and track inventory to a degree few could imagine back in the early 1980s. Recent focus has been on implementing advanced technologies that fundamentally change the way supply chains operate through a process known as *digital transformation* (Gezgin, Huang, Samal, & Silva, 2017). The traditional linear view of the supply chain is no longer sufficient to satisfy customers compared to best-in-class competitors in the industry. Traditional supply chains often suffer from delays and demand amplification through the bullwhip effect. The digital supply chain, on the other hand, views the supply chain as an interconnected network of suppliers, manufacturers, and third-party service providers focused on satisfying the customers (Sherman and Chauhan, 2016).

Firms improved their supply chain performance in the 1980s and 1990s by capturing efficiencies from collaboration and technology applications, but incremental gains quickly became harder to realize and supply chain performance plateaued as opportunities for significant improvement dried up. The transformational, data-rich technologies developed in recent years and classified under the term *Industry 4.0* enable firms to achieve breakthrough improvements in their supply chain performance. The success of a digital transformation incorporating Industry 4.0 technologies is dependent upon sufficient integration between the supply chain operations and technology applications as well as human resources and organizational structure that supports continuous improvement and innovation (Gezgin et al., 2017).

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Industry 4.0 technologies represent a revolution in the way firms can use data and automation to manage their physical operations and make better decisions. Specific Industry 4.0 applications include additive manufacturing, blockchain, automated robotics, and artificial intelligence (Olsen and Tomlin, 2020). All these technologies and methods use data to control operations or share information between supply chain partners. The focus of this chapter, however, is on one specific Industry 4.0 technology that collects and transmits real-time data that provide information inputs to other applications and help managers to make better decisions—the Internet of Things (IoT)—and how it enables organizations to improve their supply chains.

BACKGROUND

Represents the system of automated data collection and transmission via internet-connected devices that are implanted in or built into physical items (Birkel and Hartmann, 2020). The term was originally coined by Kevin Ashton in 1999 (Ashton, 2009). At this time, IoT technology was largely limited to automated identification tools such as bar codes and RFID. Modern IoT networks, however, utilize a portfolio of devices and technologies to collect, store, and transmit data such as wireless sensor and actuator networks (WSAN), near field communications (NFC), and smart devices (Atzori, Iera, & Morabito, 2010). Specific IoT devices include environmental sensors, temperature sensors, optical sensors, and wearable sensors (Caro and Sadr, 2019). Additional technologies such as smart phones, cloud computing, and social networks provide support for the IoT network (Xu, He, & Li, 2014).

Establishing and maintaining a seamless data and transmission connection between many disparate sensors, devices, and systems requires a sophisticated network architecture. Xu et al. (2014) describe the design of a four-layer, service-oriented architecture to facilitate IoT networks. The sensing layer works with the sensors and devices to collect data and control the physical items or equipment in the network. The networking layer enables transmission of the data over an Internet-enabled (wireless or wired) network. The service layer uses middleware technology to provide services to the users to satisfy their data and information needs. The interface layer allows the users and other applications to interact with the data.

The service-oriented architecture for IoT is scalable, allowing firms to add more sensors to the network or integrate new data sources as needed (Birkel and Hartmann, 2020). As a result, these IoT networks generate massive amounts of data in datasets classified as *Big Data*. The datasets meet the three standard dimensions of Big Data—volume, variety, and velocity—because they are extremely large (volume), are generated by many different sensors and devices (variety), and are collected and transmitted quickly and frequently (velocity) (Arunachalam, Kumar, & Kawalek, 2018). Firms must then apply Big Data analytics to incorporate this information into how they manage their supply chains in real time to improve performance and increase customer value.

The next section discusses specific benefits that firms can expect to realize when implementing IoT technologies within their supply chain operations.

SUPPLY CHAIN IMPROVEMENTS FROM IMPLEMENTING INTERNET OF THINGS TECHNOLOGY

Supply chain networks consist of linkages between dozens if not hundreds of organizations. All these organizations must perform their given tasks and responsibilities on time and effectively to meet the

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