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Conceptual modelling for supply chain inventory visibility

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ABSTRACT

Visibility becomes increasingly important for companies that seek to globalise their supply chains due to the increasing complexity involved. This paper contributes to the research on Supply Chain Visibility (SCV) from an inventory perspective with a focus on inventory visibility, which is a critical part of SCV. The characteristics of Inventory Visibility (IV), which are inherited from SCV, are conceptually analysed. A theoretical model in terms of atom, single, and compound visibility, is developed based on the characteristics identified. A method for objectively measuring IV is presented together with a case example to demonstrate its convenience and usefulness.

1. Introduction

With globalisation, supply chains become increasingly complex and companies are more aware of the need to have better Supply Chain Visibility (SCV). Enslow (2006) reports that the lack of supply chain process visibility is a main concern for about 79% of the 150 large companies surveyed globally. This is verified by another recent survey of 400 supply chain executives worldwide (IBM, 2009). Presently, SCV is a favourite jargon in the supply chain management community with over 7,510,000 entries found on the Web (www.yahoo.com, 9 September 2009). However, it remains a popular buzzword albeit an ill-defined and poorly understood concept in the literature (Barratt and Oke, 2007).

Indeed, SCV is a complex issue that involves people, process, technology, and information flow. From an IT perspective, SCV refers to an organisation's ability to collect and analyse distributed data, generate specific recommendations, and match insights to strategy (Tohamy et al., 2003). Bartlett et al. (2007) have shown that increased supply chain visibility can be achieved through supplier–customer collaboration. While an increase in available supply chain data provides the illusion of visibility, it also adds to a company's challenges. Moreover, 90% of all supply chains report that their global supply chain technology is inadequate to provide their finance organisation with the timely information required for budget and cash flow planning and management. The lack of visibility, complete or otherwise, is especially crippling for global supply chains, which can have pipeline inventory of $1 billion. Poor visibility and uncoordinated multi-tier processes for these companies can result in significant "just in case" inventory carrying costs, premium freight expenses, and extended cycle times.

SCV is an emergent area of interest for both practise and academe due to the advent of advanced IT technologies such as RFID and GPS (Bottani et al., 2010; Chang et al., 2010; Huo and Jiang, 2007; Melski et al., 2008; O'Neill and Newton, 2004). Despite its practical relevance, there is confusion and misunderstanding about SCV, and there is no commonly accepted definition of SCV (Francis, 2008). While some definitions for SCV exist (Barratt and Oke, 2007; Francis, 2008; Hsiao-Lan and Wang, 2007; McCrea, 2005; Rao, 2004; Tohamy et al., 2003; Vitasek, 2006; Zhang et al., 2008), they address SCV from different perspectives and have not captured the meaning, function, and essence of SCV holistically. SCV can be decomposed into inventory, demand, and logistics visibility based on the information available (Goh et al., 2009).

Inventory Visibility (IV) is an important aspect of SCV, as it provides companies with information about their inventories to make their supply chain as effective as possible. It supplies the latest and accurate data from in-stock inventory to in-transit inventory, and helps optimise the end-to-end supply chain process. Today, with RFID that enables item level track and trace (Delen et al., 2007; Griffiths et al., 2007; Zhou, 2009), some researches define SCV only from an inventory perspective. For example, Christopher and Lee (2004) highlight that many supply chains suffer from limited inventory visibility. This means that a particular entity in the network is unaware of the status of upstream and downstream operations of the levels and flow of

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inventory as it progresses through the chain. From the same perspective, Vitasek (2006) treats SCV as inventory management software applications that track and trace inventory globally at a line-item level, notifying the user of significant deviations from plan.

IV has three stages: shipment tracking, supply chain event/disruption management, and the continuous improvement of the supply chain. First, IV provides a means to track goods and materials. Second, higher IV, especially, visibility into the movement of inventory, aids better decision making in disruptive event management. Third, a measure of the degree of IV provides a key indicator for supply chain performance improvement. As IV is an emerging research topic, existing research is mainly focused on modelling its benefits and impact from different perspectives to emphasise its importance (Bottani and Rizzi, 2008; Gumrukcu et al., 2008; Lee and Ozer, 2007; Li et al., 2009; Sahin and Dallery, 2009; Yao and Dresner, 2008; Zhou, 2009). However, some research questions still persist, namely (i) how to objectively quantify IV?, (ii) what is the extent of visibility?, (iii) how to know if IV has improved?, and (iv) what is the improvement in IV?

According to the SCV maturity model (Polese, 2002), the current solutions are targeted only at the functionality of the lower maturity levels. To achieve higher levels of maturity of SCV, there is a need to objectively quantify IV for supply chain performance improvement. This paper addresses such problems by providing a means for better SC collaboration and control, and continuous performance improvement. Thus, this paper seeks to contribute to a conceptual model of IV and provide some objective quantitative methods to measure IV for an actor in a supply chain, for a set of actors, and for a supply chain.

The rest of this paper is organised as follows. Section 2 reviews the extant literature on IV. Section 3 develops the model for IV. A model based on set theory and objective quantitative methods for measuring IV is presented. Section 4 discusses the potential applications and their impact on practise and theory, and provides a case example together with a web based system to validate the conceptual model. Section 5 concludes with limitations and future research.

2. Literature review

The current research on IV mainly focuses on its importance, which can be summarised into two research streams: the impact of inventory information inaccuracy and the impact of IV on supply chain performance.

2.1. Impact of inventory information inaccuracy

Due to inventory inaccuracy, visibility is still a major issue confronting inventory management systems using AIDC technologies (Bailey and Francis, 2008; Sarac et al., 2010; Sahin and Dallery, 2009). Recent research suggests that it is unfair to assume that the availability of error free data on the flow of goods through an inventory system as well as the on-hand inventory level in facilities, where advanced item AIDC technologies are used, leads to an accurate inventory status (Sahin et al., 2008). These inaccuracies result from replenishment errors, employee theft, shoplifting, improper handling of damaged merchandise, imperfect inventory audits, and incorrect recording of sales. Rekik et al. (2009) have analysed the problem of store theft by optimising the holding cost under a service level constraint. Further, Sahin and Dallery (2009) have attempted to quantify the economic impact of poor visibility caused by inventory inaccuracy using a newsvendor framework for a wholesaler and retailers subject to inventory data inaccuracies. An assessment of the effect of various actions such as the deployment of a new data capture technology to tackle inventory inaccuracy is also studied (see e.g. Uçkun et al., 2008).

Fleisch and Tellkamp (2005) use simulation to show that better IV, by eliminating inventory inaccuracy, can reduce a three-echelon supply chain cost as well as the out-of-stock level. The same conclusion has been drawn by another simulation of a two-echelon inventory system consisting of a retailer, a distribution centre, and a supplier that includes multiple item types and using cycle counting as the corrective action (Gumrukcu et al., 2008).

2.2. Impact of IV on supply chain performance

IV is critical for supply chain performance improvement and IV is identified as a significant performance indicator by Daugherty et al. (2006) who also discussed the importance of measuring IV. However, there is no measurement method yet. Chan (2003), through AHP, presents a formulisation of both quantitative and qualitative performance measurements for easy representation and understanding using visibility. Berry and Naim (1996) simulate the implications of various supply chain redesign strategies for the introduction of an IV system to a European PC maker. The benefits of IV and its improvement based on a global demand supply network are also reported in a case study (Kaipia and Hartiala, 2006). Goel (2010) conducts a case study to quantify the benefits of gradual increase in the level of visibility for a supply chain in the automotive industry. Caridi et al. (2010a) study that up to what extent the supply chain configuration affects the supply chain visibility in terms of virtuality and complexity. They (Caridi et al., 2010b) also present a subjective measure of visibility for each supply chain node by combining overall judgments of visibility quantity, accuracy, and freshness to improve supply chain performance.

3. Model development for IV

IV is the capability of a supply chain actor (or player) to have an access to or to provide the required timely information/knowledge about the inventory involved in the supply chain from/to relevant supply chain partners for better decision support. There are two types of capability, namely, the capability to access information available in a supply chain and the capability to provide information available in a supply chain. Likewise, information/knowledge focuses on information or knowledge about physical inventory entities in a supply chain such as the stock level in a certain warehouse, which can be accessed via IT systems. It is impossible to deal with physical inventory entities directly in this study. The information/knowledge provide relevant state mapping of the physical world. However, the accuracy of the information about the physical inventory is an issue related to IV. Timeliness is an important factor for IV. The capability to provide or access information must be measured using a timeliness metric. Any out-of-date information about an entity in a supply chain has a negative impact on IV. The final objective of IV is for decision support, which should be able to be measured in terms of capability using a mathematical model.

Based on the above understanding of IV, a model can be developed using set theory.

3.1. Framework for IV

Consider a supply chain (see Fig. 1) with m actors/players and n information items/resources sharing in a supply chain using a four-tuple $SC=(A, I, C, P)$, where