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Improving inventory effectiveness in RFID-enabled global supply chain with Grey forecasting model

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ABSTRACT

A RFID-enabled global TFT–LCD supply chain associated with Grey forecasting model (GM) of Company A has been simulated and analyzed in this research. Three key performance indicates (KPI) including total inventory cost, inventory turnover and bullwhip effect are analyzed in the simulation experiments in order to compare the effectiveness of five different supply chain inventory models. The effectiveness of integrated system which is composed of supply chain operation, Grey short-term forecasting model and RFID system has been examined by aforementioned three KPIs. According to the result of Taguchi experiments, RFID-enabled *R-SCI*$_{GM}$ supply chain model which integrates the GM(1,1) forecasting model based on (*s*, *Q*) pull-based replenishment policy reduces 43.36% of the total inventory cost compared with that of the non-RFID *SCI*$_{GM}$ model. It apparently shows that a great improving effectiveness of supply chain inventory cost can be conducted while RFID system is incorporated with the GM(1,1) forecasting model.

1. Introduction

There has been fierce competition between companies under the trend of globalization of industries. Therefore, the problems of reducing the length of product lifecycle, tightening shipment date and quick delivery of products are faced by the industries. In order to achieve the ultimate value of integrated operations, industries are going to focus on the integration of supply chain. The interrelated networks of supply chain consist of manufacturers, suppliers, distributors, wholesalers, retailers and customers. The volume of demand forecasted by upstream suppliers is usually greater than the actual market demand, for the lack of transparent information and communication channel. The wrong decisions on inventory and production are caused by the distorted information on purchasing products. Thus, the increased inventory cost in the upstream channels leads to the enlargement of the total cost of entire supply chain, which creates the bullwhip effect.

Lee et al. (1997) considers demand forecasting, lead time, price variation and batch orders as factors of bullwhip effect. He thinks one of the ways to weaken bullwhip effect is to avoid repeated demand forecasting. To lessen the problem of bullwhip effect, the sharing and exchanging of supply chain information is needed. For achieving this goal, one way is to utilize the Radio Frequency Identification System (RFID). With the real-time product visibility and traceability of RFID, the amount of on-hand inventory across supply chain tiers can be precisely calculated, and the lead time of product delivery can be shortened. Moreover, the impact which results from errors in demand forecasting can be reduced, and the effectiveness of supply chain management can thus increase. In order to cope with the instant RFID-enabled information sharing capability, the Grey forecasting model can be appropriately adopted based on merely four pieces of short-term historical data.

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Therefore, there is a great opportunity for integrating the real-time data retrieval capability of RFID with short-term forecasting merit of GM to achieve the quick response in the operation of supply chain.

The purpose of this research is to establish a simulation model of global supply chain, which integrates the Grey short-term forecasting model and specific service level as basic pull-based inventory replenishment policy for the TFT–LCD Company A, to prove that the implementation of RFID system can best improve the inventory cost effectiveness.

The remainder of this paper is organized as follows: Section 2 provides a literature review on the RFID applications, supply chain simulation and Grey forecasting model. The global TFT–LCD RFID-enabled supply chain of Company A and simulation modeling is presented in Section 3. The Taguchi methods/design of experiments and verification by simulation are described in Section 4. In Section 5, the experiment results of simulation KPI output are analyzed and compared. The conclusion of this research is shown in Section 6.

2. Literature review

2.1. RFID applications in supply chain

Saygin et al. (2007) design methods for establishing a RFID-enabled nonlinear supply chain system and emphasize the communications infrastructure necessary to provide seamless data and information flow in order to achieve RFID data-based decision-making at all levels of supply chain. By providing visibility, effective RFID implementation in a supply chain can bridge the gap between the shop floor and higher level operations. Mills-Harris et al. (2007) conducted a simulated study on the inventory management of time-sensitive materials, based on data collected by RFID. They provide three inventory models which rely on RFID data and design the trend-adjusted inventory forecast model in accordance with five estimating indicators. The result shows that a proper adjustment of the two smoothing parameters (α and β) can achieve the system performance demanded. Moreover, in January 2005, a successful trial of the RFID/EPC system on tagged pallets and cases was done by Wal-Mart and its top 100 suppliers. The University of Arkansas analyzes Wal-Mart's success and finds that after adopting the RFID/EPC system, there's a 16% decrease in the out-of-stock rate (MHM, 2005). Hardgrave et al. (2005) did research on 24 retailers of Wal-Mart, which are divided into two groups, and each group consists of 12 retailers. The result shows that the group which implements RFID has a 26% decrease in the out-of-stock rate and has improved by 63% compared to the group without RFID. Delen et al. (2007) analyze the RFID data collected from retailers and suppliers in supply chain and want to know how to estimate the time needed from the logistics center to retailers through RFID. Lee et al. (2004) of the IBM prove the potential effectiveness of RFID in decreasing the inventory and enhancing the service level with simulation methods based on real data, and the model is a three-tier supply chain.

These studies above only involve parts of the supply chain tiers, but do not take the interrelation of the entire supply chain into account. Therefore, this research takes Company A's global supply chain of TFT–LCD as an example, designs a simulation model to mimic the operation process of RFID-enabled global supply chain, and uses experimental design methods to prove the potential effectiveness of RFID in improving the supply chain inventory management.

Visich et al. (2009) conduct an investigation of actual benefits generated by RFID system on supply chain performance through empirical evidence. The research work of RFID in supply chain is divided into three areas: RFID overview, empirical studies and analytical studies. This study shows that automational effects of RFID on operational processes include reduced cost, improved shipping and receiving efficiency, improved inventory control, reduced inventory cost and reduced throughput time. One of the major automational effects is in the area of inventory control. Ngai et al. (2008) organize RFID research into four main categories: technological issues, applications areas, policy and security issues, and other issues. Supply chain management is one sub-category for RFID applications. They conclude that there has been relatively little work done on impacts on the sales and marketing.

Sarac et al. (2010) also conclude that potential benefits, inventory inaccuracy problems, the bullwhip effect and replenishment policies are the major research on the impact of RFID on supply chain management. Simulations study is one major reviewed methodology. Zelbst et al. (2010) construct a structural model to assess the impacts on the supply chain performance based on the utilization of RFID technology and supply chain information sharing. Kok and Shang (2007) develop an inspection adjusted base-stock (IABS) policy for inventory replenishment in the single-period problem to optimize the inventory cost. They indicate that the IABS heuristic can achieve a significant value of accurate inventory information provided by RFID systems.

The motivation of this research is stemmed from those above research findings. We mainly focus on the evaluation of impacts on the satisfaction of customer requirements and reduced total inventory cost in RFID-enabled supply chain. Therefore, this research has integrated the Grey short-term customer orders forecasting model with different pull-based replenishment policies within RFID-enabled supply chain and simulated its effectiveness on the total supply chain inventory cost.

2.2. RFID-enabled supply chain simulation

Kleijnen (2005) surveys four types of supply chain simulation: spreadsheet, system dynamics (SD), discrete-event dynamic system (DEDS), and business games. The survey concludes that the DEDS simulation is an important method in