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RFID versus bar-coding systems: Transactions errors in health care apparel inventory control

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ABSTRACT

In recent years, RFID technology has been a popular topic in inventory management. However, whether this technology is superior to the traditionally used systems such as bar-coding system is controversial. In fact, prior empirical studies have revealed that the (observed) successful read rate in real world RFID applications is just in between 60 and 70%. In this paper, motivated by this fact and the observed industrial practice of apparel control in health care organizations, we first conduct an analytical study to reveal when RFID systems will outperform the bar-coding system (and vice versa) in terms of reduction of the amount of required safety stock. We then extend our analysis to a supply chain context which includes the upstream apparel-product supplier and the downstream health care organization. We analytically prove several important insights which include: (i) The ratios between the RFID and bar-coding systems' stock-taking costs and error variations will determine whether one system outperforms the other. (ii) No matter whether the health care organization changes its scanning system from bar-coding to RFID or from RFID to bar-coding, it will only benefit the health care organization but the supplier will suffer. (iii) A carefully designed surplus sharing contract can create a win–win situation under which both the supplier and the health care organization will have improvement (in cost or profit) with the change of the scanning system. Implications are discussed.

1. Introduction and related literature

The industry of textiles and clothing (fashion) is characterized by short product lifecycles and highly uncertain market demand [2,8]. Different philosophies have been developed to cope with market uncertainty, for instance, just-in-time inventory systems and efficient consumer response programs [26]. Success for many fashion companies hence relies on effective and efficient supply chain management scheme. Among various technological advances, RFID system is a tool which has been generally believed to be beneficial to fashion supply chain management. RFID system's idea is based on the use of radio frequency as a way of transmitting information. RFID tag, which is an integrated circuit with an antenna, can be attached to any product and package. With wireless technologies, companies can easily keep track of the RFID tag without any physical contact. Inventory tracking becomes easier than ever and many other probable applications of RFID technologies, such as customized services for customer relationship management, have been proposed. In the fashion industry, it is well-agreed that the use of information is a crucial part of supply chain management [7]. It helps to alleviate challenges such as the bullwhip effect and achieve important policies such as accurate response [14], and quick response [6,8]. The establishments of RFID technologies are widely believed to provide efficient and effective tools to facilitate information flow and inventory visibility along the fashion supply chains [17]. In light of the successful cases of RFID implementation for tracking and controlling clothing in apparel retailing such as Marks and Spencer (M&S) [10] and Gap Inc. [1], its application has spread over to the health care industry such as handling the pharmaceutical inventory [4], monitoring Alzheimer patients [11], and managing bottle gas delivery [27]. Recently, it has also been extended to manage the health care apparel products to improve operations efficiency, reduce health care apparel inventory level, and attain substantial saving. Following are three RFID deployments in the health care organizations that illustrate the impact on apparel inventory management, distribution, and workflow of medical staff.

In 2006, a Norwegian health care center, St. Olav's Hospital, implemented an RFID-based uniform-tracking system to replace traditional paper-based system to cope with more than 130,000 work garments in daily operations [29]. The employees use their hospital identification cards to access the uniform storage locker, and once they have taken away the uniforms and closed the door, an RFID reader will be activated to read, count and update the number of uniforms remaining inside the locker. Additionally, when the quantity of uniforms falls below the preset level, they will replenish the locker up to the desired level. Another RFID reader is attached to specific bin which collects used uniforms for laundering. The interrogator transmits

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the data to the back-end software, regarding the garment IDs and time of those garments submitted to laundry. This system saves an estimated 40 million kroner in space savings for the removal of conveyor system and the hospital believes in big saving each year compared to the manual system through improving inventory accuracy and labor reductions. The RFID system not only enhances the real time visibility of staff garments within the hospital, but also associates the patients' garments for automated distribution across different hospital sites. Another promising RFID adoption occurred in Switzerland. Four Geneva-based university hospitals were merged to form the University Hospitals of Geneva (HUG) in 1995 [37]. HUG is now a large scaled hospital that offers both inpatient and outpatient services. Each patient's garment is sewn with an RFID tag which stores only the item ID and information related to laundry service. Interestingly, this RFID system is used to identify and match the tops with the bottoms of the patient/staff garments, as well as the whole set of garment with the corresponding site after laundering. The automated garment distribution provides 24 hours 7 days a week service to employees and smoothens the garment handling process of collection, ironing, redistribution across 4 sites with 7 distributors, and 28,000 garments allocation per week efficiently. Besides, it monitors the number of times that a piece of garment has been washed for determining whether the garments fulfilled the quality claimed by the suppliers. Furthermore, the hospital reduces the garment inventory level and saves up to 30% of the total garment expenditure. Apart from tracking the uniforms, a public hospital in Northern Germany, the Bielefeld City Clinic, launches trails to evaluate the feasibility of adopting RFID system to ensure that beds and mattresses can be cleaned appropriately, in a time and cost efficient way [39]. Beds and mattresses are equipped with passive RFID tags to distinguish one from another. Nurses depend on the patient's illness level to determine the type of cleaning of the bed, for example, a completed disinfection is needed if a patient is suffered from highly infectious disease. This information is input to the hospital's bed management software so that the cleaning staff can clean the beds and mattresses according to the instructions recorded. Once the laundering is completed, the system is updated to indicate the types of cleaning performed and record the number of beds and mattresses available. The clinic is expected to acquire cost saving from a lower stock level of beds and mattresses and fewer working time of the staff.

It seems that both fashion and health care industries can achieve sustainable benefits if RFID system is adopted to deal with the apparel products in their operations. However, regarding the business value of RFID systems, industrial reports, white papers, newspapers, and magazines are all filled with guesses. For example, some industrial reports, such as AMR Report, have estimated that the use of RFID systems can reduce supply chain cost by 3 to 5% and increase revenue by 2 to 7% (see [2,24]). Doubtless to say, it is believed that none of the scanning system is 100% reliable and error-free to reflect the real data and inventory level [9,28]. Our discussions with various industrialists have indicated that RFID systems need not outperform the traditional systems such as bar-coding systems because the barcode system possesses a higher reliability on read rate [5]. There are actually failure cases with the use of RFID technologies in inventory management (see [31,38] for details). Existing studies also comment that RFID is also suffering from read rate inaccuracy [34,35] and the observed successful read rate in real world RFID application is often just in between 60 and 70% [13,16,20]. The stability of RFID on reading the tag depends on various environment factors such as tagged object, tag placement, angle or rotation, and read distance [30,41]. For example, a pilot study examines the reliability of the RFID for tracking the location of nurses, patients and medical equipment in a hospital [30]. The RFID antennas are placed at the ceiling over the patient's room entrance and at the bedside while the RFID tags are attached to different body positions (chest, neck or wrist) of the nurses. Results show that it is more appropriate to posit the tag near the chest but if two nurses walk under the antenna at the same time, the accuracy of the tag reading drops by about half. Therefore, when the tags are fitted in the health care apparel for enhancing the inventory management, one has to take the tag position into the account that it will affect the RFID reading accuracy. As a result, we cannot simply conclude that RFID is superior to the barcode system in all situations without any in-depth investigation. To clearly show the literature positioning of this paper, a systematic comparison between this paper and the other closely related papers is shown in Table 1.[1] From Table 1, we can see that this paper is the first one which analytically compares the inventory accuracy issue between the RFID and the bar-coding systems based on the respective transaction errors. In addition, this paper is rather unique because it also examines the supply chain coordination issue and focuses on healthcare related operations.

In this paper, we conduct an analytical study on developing the conditions in which RFID systems would be preferred when compared to bar-coding systems for apparel inventory control in the health care sectors. We also explore the respective business value of switching from bar-coding to RFID systems. By extending the study to a supply chain context (which includes an upstream supplier and the downstream health care organization), we further investigate whether and how win–win situation (i.e. both the supplier and the health care organization can have cost or profit improvement with the change of the scanning system) can be achieved in the supply chain. Insights are generated.

The remainder of the paper is organized as follows. In Section 2, we consider the accuracy of scanning systems and introduce the related model for analysis. In Section 3, we compare the business value and derive the analytical conditions that RFID system outperforms the bar-coding system (or vice versa). If the health care organization changes the scanning systems, the impact on the supplier is analyzed and presented in Section 4. Following the analytical results, we propose the use of a surplus sharing contract to achieve win–win situation between the supplier and the health care organization in Section 5. We conclude in Section 6. To simplify our exposition: (i) we use the subscripts B and R to represent bar-coding system and RFID system respectively throughout the paper, (ii) all detailed mathematical derivations and proofs are provided in Appendix A.

2. Model

Following the work by Iglehart and Morey [19], we consider a challenge with inventory accuracy owing to the data error such as scanning error (i.e., the computer record does not give the true picture on inventory level) for apparel items in a health care organization. To start with, we focus on one product item and consider the health care organization is employing a multi-period periodic review inventory system with a stationary (s, S) policy. Demand is stochastic and would come from time to time. In the health care organization, transactions are recorded electronically by scanning methods. We compare two data scanning systems: RFID (R) and bar-coding (B). Since there are data errors, periodic stock checking is necessary and suppose that there are N_i periods between stock checking, where $i \in \{B,R\}$. Let h be the inventory carrying cost per item per period and J_i be the cost of conducting stock checking, where $i \in \{B,R\}$; J_i is given by $C_1 + C_2 T_i$, where C_1 refers to the fixed cost of conducting stock taking (e.g., the use of full-time staff members), C_2 refers to the time-dependent cost of conducting stock taking (e.g., the use of part time staff), and T_i represents the time required to conduct stock taking for $i \in \{B,R\}$. Notice that in this paper, we consider the commonly observed case in which J_i is a much bigger expense compared to the inventory holding cost incurred for an item. Following the literature [12,19,22], we model the data error $e_{i,t}$, for $t = 1, 2, \ldots, N_i$, as an independent, identically distributed (iid) random variable following a normal

[1] We thank the anonymous reviewers for pointing out the need of strengthening the literature positioning of this paper.