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Warehouse efficiency improvement using RFID in a humanitarian supply chain: Implications for Indian food security system

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ABSTRACT

This paper investigates the impact of RFID adoption in a non-profit supply chain scenario to study the effect of *available rate of ordering* and *shrinkage recovery rate* on overall costs at the warehouse level. We model the situation as a Newsvendor problem with the objective to minimize the total expected cost and compare two scenarios with and without RFID for managing the inventory subjected to shrinkage and misplacement. We apply the model to Indian food security system and the results show that, incentive to deploy RFID depends on the deprivation cost, the severity of error and the shrinkage recovery rate.

1. Introduction

Efficiency improvement in humanitarian supply chain has been a major challenge due to involvement of complex list of stakeholders and has drawn the attention of both academics and not-for-profit organizations (Chandes and Paché, 2010; Christopher and Tatham, 2014; Kovács and Spens, 2009). Such supply chains can be broadly classified into two categories: *short-term ones* those operate during disasters such as earthquake or hurricane, or slow-onset, such as drought or famine, and the *long-term* ones those provide consistent assistance to a group of socially deprived community (Çelik et al., 2012). Examples of some long-term humanitarian issues include food insecurity, high mortality from diseases and gender inequality, which are mostly covered under the Millennium Development Goals (UN, 2017). Though, most of the literature on humanitarian supply chain revolves around short-term disaster management; long-term developmental supply chain covering a gamut of human life issues like food security, health care, education and gender equality deserves equal attention. For example, the United Nations acknowledges hunger and malnutrition as the greatest risk to world health. Accordingly, eradication of extreme poverty and hunger remains the first of the eight objectives defined under the Millennium Development Goals (UN, 2017).

Performance in the context of such supply chains is predominantly measured in terms of *cost* and a combination of cost and *customer responsiveness* (Beamon, 1999). Cost components primarily include inventory costs, operational costs and deprivation costs (Holguín-Veras et al., 2012) whereas lead-time, stockout probability, and fill rate are the measure of customer responsiveness. Lack of skilled human resource, low recognition of logistics, inadequate infrastructure, and resource wastages are some of the leading challenges of both short-term and long-term humanitarian supply chain (Kovács and Spens, 2009). Specifically, in food security systems such as Indian Targeted Public Distribution System (TPDS), wastage of resources through spoilage, leakage, and theft are the primary cause of concern (CAG, 2013; Drèze and Khera, 2015).

The spoilage and misplacement of stocks never get reconciled on a real-time basis, which is the source of inventory inaccuracy in such supply chains. Inventory inaccuracy refers to the discrepancies that exist between actual inventory available and what is on the record of the information system. This primarily arises from three main sources namely shrinkage, misplacement, and transaction

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errors (Atali et al., 2009; Fan et al., 2015). Shrinkage includes theft of inventory, spoilage, obsolescence, supplier fraud, and damage resulting in reduced actual inventory as compared with system record. Misplacement errors occur when a part of the inventory is not available to satisfy customer demand although physically present (Rekik et al., 2008).

Radio Frequency Identification (RFID) technology is considered as a promising solution to address the problem of inventory inaccuracy. This is an Automatic Identification and Data Capture (AIDC) technology, which enables real-time communication with numerous objects simultaneously from a distance without line of sight (García et al., 2007). This unique and advanced tracking capability enables RFID in reducing inventory shrinkage, directly by preventing theft and fraud through accurate monitoring, and indirectly by enhancing accuracy of information and improved visibility (de Kok et al., 2008; Lee and Özer, 2007; Pero and Rossi, 2014; Rekik et al., 2009). RFID technology can be used to improve efficiency and responsiveness both in *short-term* and *long-term* humanitarian supply chain. During disaster, responding quickly to the need of the victims is the prime concern and the ability of RFID technology to track the critical resources like food, medicine, equipments and human resource would greatly reduce the response time (Yang et al., 2011, 2013). It can also improve the security and management aspects of the relief supply chain (Baldini et al., 2012). Similarly in long-term humanitarian supply chain the situation is comparatively stable and efficiently achieving the social mission is the prime concern (Baruch and Ramalho, 2006; Holguín-Veras et al., 2012, 2013). Application of RFID technology can improve operational efficiency in terms of lower inventory, reduced stock out, and better utilization of resources.

Although RFID technology has gained traction in the for-profit sector, the same cannot be claimed for the non-profit supply chain. Most of the technology projects in such supply chains are donor funded, and without realistic estimation of the benefits it is difficult to get the go ahead for the project (Maiers et al., 2005). The traditional modeling approach while estimating value of RFID may not give accurate result in a humanitarian scenario. This is because, along with operational efficiency, the reduction in human suffering due to technology intervention should also be suitably accounted for in the objective function for realistic estimation of the value of RFID (Holguín-Veras et al., 2013). The models used in the existing literature do not consider this aspect.

In this paper, we explore the possibility of deploying RFID technology in warehouses operating under non-profit scenario and facing inventory inaccuracy issues. We model the situation as a newsvendor problem to quantify the benefits by comparing two scenarios – with and without RFID. This generic setting is further analysed under uniformly distributed demand to derive the closed-form expression for optimal order quantity and total expected costs for both the scenarios and tag cost under which RFID deployment is feasible. We apply the model in the context of Indian food security system collecting the data from different resources and field visits. We perform sensitivity analysis on the parameters for which exact values are not available from any source. Our observations show that RFID is not beneficial when the shrinkage and misplacement level in the warehouse is less than a critical value. The critical tag price below which the system with RFID becomes viable is dependent on level of shrinkage and misplacement, shrinkage recovery rate and deprivation cost factor. When the shrinkage in the warehouse is high, RFID is viable even at higher tag price. Similarly a better shrinkage recovery rate justifies higher tag cost. We also estimate the potential cost saving for a 50,000 MT warehouse with RFID.

Our work is motivated by Fan et al. (2014) and (2015). However, we differ from them in many ways. Fan et al. (2014) model inventory inaccuracy by considering only the shrinkage. They neither consider inventory misplacement nor do they incorporate the fixed cost of RFID implementation. Although, these two issues are addressed later in Fan et al. (2015), they study the impact of RFID in a profit maximization scenario. While their model applies to for-profit organizations, it is restrictive in a humanitarian supply chain context due to the following reasons. First, the warehouses under non-profit scenarios need to suitably account for the reduction in human suffering along with operational efficiency (Holguín-Veras et al., 2013). Second, procurement cost in a non-profit scenario does not make much sense as the cost is directly reimbursed by the donor. Hence, procurement cost does not contribute to total operational cost of the warehouse. Third, they calculate shrinkage based on the selling price. However, in non-profit scenario warehouse is only responsible for distribution. Hence, sales price is not meaningful. The model proposed in this paper fills this void.

We make three significant contributions. *First*, our model is unique in that, we incorporate deprivation cost to account for the human suffering due to delay in delivery of critical items. *Second*, we jointly consider shrinkage and misplacement in a cost minimization scenario and derive closed-form solutions for *the critical tag cost* and *threshold value of shrinkage recovery rate* under uniform demand distribution. The solutions developed in the earlier literature are not applicable due to the unique nature of our model. *Third*, while most of the papers have numerical illustrations using hypothetical data, we consider the data for Public Distribution System of India and interpret the result. To sum it up we are the first to quantify the benefits of RFID in a not-for-profit scenario considering shrinkage, misplacement and deprivation cost in the model.

The rest of the paper is organized as follows. In Section 2, we review the related literature on humanitarian supply chain, RFID application in humanitarian supply chain and the application of RFID to address inventory inaccuracy issue. In Section 3, we model the inventory inaccuracy issue in a warehouse under two different scenarios with and without RFID. In Section 4, we apply the model in the context of Indian food security system and analyze the effect of available rate of ordering, shrinkage recovery rate after RFID implementation, and the tag price respectively. We also provide an analytical expression of the tag cost, which makes the deployment of RFID a viable option. In Section 5, we discuss the managerial implications and finally, in Section 6, we conclude the study and show direction for future research.

2. Related literature

2.1. Humanitarian supply chain

Disasters and *Long-term development issues* are the two key terms in the context of humanitarian supply chain. Disaster is an event