European Journal of Operational Research 000 (2015) 1–11

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Production, Manufacturing and Logistics

The expected value of the traceability information

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ARTICLE INFO

Article history:
Received 3 December 2013
Accepted 15 January 2015
Available online xxx

Keywords:
Traceability systems
Quality control
Supply chain optimization

ABSTRACT

Recent regulations on agri-food traceability prescribe traceability throughout the entire supply chain, in order to ensure consumers' safety and product quality. This has led producers and retailers to consider the opportunity to improve the firm's reputation and consumer confidence through the implementation of traceability systems designed not only to satisfy the legal requirements, but also to track the quality of the products through the supply chain for optimization purposes. However the actual implementation of such systems depends on the possibility of gathering specific information related to the product quality. Nowadays, innovative and non invasive technologies such as the Radio Frequency Identification (RFID) allow the automatic real time collection of data, thus enabling the development of effective traceability systems. In such context the expected value of traceability is a fundamental issue concerning the economic analysis of costs involved in such an investment and the optimal granularity level of implementation. This paper aims at evaluating the expected value of the implementation of traceability systems for perishable products like fruits and vegetables, and its profit. The study presents a mathematical stochastic approach for optimizing the supply chain profit and establishing the optimal granularity level (namely the Economic Traceability Lot) when a RFID solution is adopted. In particular, the supply chain profit in the presence of RFID traceability system has been calculated and compared with the expected profit in absence of such a system, and the results confirm the importance of the specific characteristics of the supply chain in determining the optimal configuration of the traceability system.

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1. Introduction

The optimization of the logistic operations for perishable products is a research topic which has attracted a significant interest due to the recent regulations on traceability aimed to ensure the consumers about the quality and safety of foods.

According to the ISO 9001:2000 standard, supply chain traceability is the ability to trace the history, application or location of an entity by means of recorded identifications (EC Regulation no. 178/2002; Nguyen, 2004), throughout the entire supply chain. In practice, supply chain traceability is an integrated end-to-end process, in which all the supply chain members contribute to optimize the tracking activity, which is achieved when the actors involved keep records of suppliers and customers and exchange this information along the entire supply chain (Cimino et al., 2005; Opara, 2004). Supply chain traceability has become a legal obligation within the EU since 1st January 2005, therefore it has attracted considerable attention in the last years. Moreover the food companies must consider the significant expenditure required to implement a traceability system as a long-term strategic investment to create consumer confidence both in the company image and in the specific product. On the other hand it has been pointed out the importance of synchronizing the activities of all partners in the supply chain in order to improve the effectiveness of supply chain operations. In this context the implementation of systems facilitating information sharing on various activities and the coordination between internal and external partners within the chain is enforced (Gunasekaran & Ngai, 2004). In addition to systematically storing information that must be made available to inspection authorities, other requirements for traceability exist besides the mere legal conformity: the members of the supply chain should in fact consider the opportunity of improving food safety and quality in order to increase the market value of products (Food Chain Strategy Division, Food Standards Agency, 2002). For this purpose, the data recorded must univocally identify the products flowing through the supply chain and provide several other information as for example, the quantity or nature of products, the weight, the remaining quality or their deterioration level, etc. In this context a proper design of a traceability system may allow to limit the product recall only to the products actually affected by contamination (Pouliot & Sumner, 2008). Such design relates not only to the procedures to be implemented and the

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http://dx.doi.org/10.1016/j.ejor.2015.01.028
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standards to be observed but also to the optimal size of the batch to be tracked along the chain. However the design, implementation, and management of an efficient traceability system for food products is a difficult task since their quality is frequently conditioned by the harvesting means, transformation processes, transporting ways, and storage conditions (De Cindio, Longo, Mirabelli, & Pizzuti, 2011), making the data gathering and management a difficult task.

When a traceability system is implemented the supply chain members can be interested in getting not only the information required by the legal regulation but also additional information concerning the product quality in order to increase consumers' fidelity and market value. In fact when the products managed are perishable a traceability system can be usefully employed to monitor the product quality by detecting and recording the factors responsible of the deterioration processes. Given the importance that environmental parameters have in keeping of product quality level during postharvest phases, they have gained the attention of researchers. Brash, Charles, Wright, and Bycroft (1995), for example studied the relation between the respiration rate expressed in terms of CO_2 emissions of a product stored at fixed temperature and its quality in terms of Shelf Life (SL) of asparagus; Zheng and Wolff (2000), focused on the relation between remaining quality, expressed in terms of product deterioration rate, and ethylene production in some varieties of melon. They showed a linear relation between the ethylene emission and the postharvest decay rating assessed through a visual inspection of products. Liu, Kakihara, and Kato (2004) studied the internal ethylene production during the postharvest phase of some varieties of melons determining their relation; Gabler (2005) found a distinct relationship between time dependency of the gas concentration and remaining quality at examinations of lettuce and other fruits. The literature about the relationship between the temperature and the quality of a product is very extensive. See for example Taoukis, Koutsoumanis, and Nychas (1999), Corbo et al. (2004), Limbo, Torri, Sinelli, Franzetti, and Casiraghi (2010), Aiello, La Scalia, and Micale (2012), that proposed some methodological approaches to the study of the relation between the product quality and the temperature history of products. Further studies in the field of quality monitoring and traceability concern the intelligent packaging allowing evidencing the non-conformity by means of a sensor-based detection technology (see for example Lee & Rahman, 2014, chap. 8; Puligundla, Jung, & Ko, 2012; Zhuang, Barth, & Cisneros-Zevallos, 2014, chap. 18). Such techniques generally rely on the assessment of the actual level of environmental conditions inside the packaging and the discarding criteria are based on a fixed threshold identifying a maximum level of the environmental parameter concentration allowed.

In this context recent pervasive and non invasive technologies such as the Radio Frequency Identification (RFID) facilitated the task of data acquisition by allowing the automatic gathering of information needed to the traceability system thus reducing the traceability costs (Dabbene & Gay, 2011). As reported by Sari (2010), RFID have been proven to improve the supply chain performance in several application fields. Shah Jaymeen, and Murtaza Mirza (2008) observed that the automated collection and transmission capabilities provided by the RFID allow enhancing information sharing and collaboration between supply chain partners. Gandino, Montrucchio, Rebaudengo, and Sanchez (2009) reported that the adoption of an automated traceability system based on RFID technology allows increasing the efficiency of the traceability management by reducing the labor cost. In particular one of the most important issues to be faced in the adoption of a traceability system is the appropriate level of traceability to implement and the costs due to the automated traceability system consequently. A survey about the use of RFID in agriculture for environmental detection can be found in Ruiz-Garcia and Lunadei (2011). The availability of real-time data has a major influence on the optimal ordering quantity and the optimal time of promotion decision. An information system, viewed from an infrastructural and managerial perspective, has various elements such as identification and collection of relevant data elements, communication and processing of the data at regular intervals etc. (Raghuram & Rangaraj, 2003). RFID technology is an emerging trend in this field and is mainly used for product identification, collection and communication of relevant data. The use of non invasive technologies like RFID in conjunction with predictive models such as that above mentioned can be easily coupled to determine the remaining quality of a product at any stage of the supply chain thus enabling proper withdrawal of non conforming ones.

This paper considers an RFID-based methodology for inventory control of perishable products such as fruits and vegetables. RFID technology requires very little or no handling of items and is therefore well suited for inventory control of perishable products. The technology also helps in updating the inventory status in real time without product movement, scanning or human involvement.

In the present paper the attention is focused on the possibility to implement such an automated traceability system for monitoring the quality level of products. The traceability system considered makes use of an RFID system for the real-time detection of food quality depending on environmental parameters. More specifically the paper focuses on the study of the economic impact of an advanced traceability system enabled by the RFID technology on a supply chain delivering perishable products like fruits and vegetables which are harvested and then sent to the retailer who will sell them to the target market. The aim of the study is to demonstrate how a properly designed traceability system can improve the efficiency of the supply chain thus generating a value, rather than being a mere cost, which is generally the perception of supply chain managers and actors. In particular the paper tackles the problem of determining the optimal granularity level of an automated traceability system through a mathematical modeling of the related costs and benefits. The effects of the inherent uncertainties are also taken into account in a general stochastic formulation aimed at determining the configuration that maximizes the expected value of the traceability system.

The paper analyzes a simple supply chain composed by a producer who provide for the harvesting and collecting of products and a retailer and determines the configuration for the traceability system to be profitable for the supply chain. The goal of the study is to show that the implementation of a properly designed traceability system based on advanced technologies not only improves the quality and safety of products, but it can also be a profitable investment for the supply chain. The remainder of the paper is organized as follows: Section 2 faces the problem of cost of traceability systems and introduces the topic of granularity of a traceability system and the choice of the optimal batch size; Section 3 provides a brief introduction on RFID technology; Section 4 relates to the proposed methodology; Sections 4.1 and 4.2 present the approach formulation; Section 5 illustrates a numerical application of the approach; Section 6 reports the conclusions.

2. The costs related to traceability systems and to the traceable unit

One of the main features that affects the cost and the practicability of traceability systems is the level of granularity. Following the definition formulated by Karlsen, Dreyer, Olsen, and Elvevoll (2012), granularity refers to the size of a traceable unit and the number of the smallest traceable units necessary to make up the traceable unit at a specific granularity level. As reported by Angeles (2005), usually the traceability levels considered are three: pallet, case or item-level. The main advantage of the item-level compared to the pallet level is the accuracy of information provided. By consequence with item level traceability in the case of recall it will be possible to reduce the number of products discarded since a lesser number of items will be withdrawn. On the other hand the finer the traceability, the higher will be the cost of the system and the amount of data to be processed.

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