



A production planning model to reduce risk and improve operations management

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ABSTRACT

Traceability has become an essential business function to consistently supply quality and safe food products to consumers. However, it has been not rare that the efforts in traceability are separately made from routine operations management decisions. In this paper, an integrated optimisation model is developed in which the product safety related traceability factor is incorporated with operations factors to develop an optimal production plan. The model aims to improve traceability and manufacturing performance by simultaneously optimising the production batch size and batch dispersion with risk factors. Two industrial cases are used to support numerical analyses to investigate the benefit under various business situations and product features.

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1. Introduction

With frequently reported food quality and safety incidents and new legislations, traceability has become an essential business function to consistently supply quality and safe food products to consumers in food industry (EU Regulation, 2002). Many efforts are being undertaken to rebuild the consumer confidence by implementing production protocols, information technology and supply chain management processes to improve quality and safety control through supply chains.

Food traceability does not only deliver an extra guarantee for food safety but also provides transparency of the value chain towards consumers (Fritz and Schiefer, 2009). The existing research mainly focuses on applying sophisticated technologies and information systems to enhance the traceability management. However, the cost required for the investment on those technologies and systems certainly impede the enthusiasm of organisations in pursuit of efficient traceability systems. This research investigates a new approach to integrating food traceability management with operations management processes. An integrated production planning model is proposed where the risk related traceability factor is incorporated with operations factors to optimise the overall performance of a manufacturing system. The research quantitatively investigates the benefits from the seamless integration of operations planning with strategic

considerations on food traceability and risk issues through the proposed production planning model. Two industrial case studies are presented to help understanding of the proposed integration strategy.

2. Literature review

The food industry is under pressure to improve product safety and quality, implement efficient risk management and rapid response capabilities to risk through full traceability. A traceability system is described as a recordkeeping system with documented identification of the operations which lead to the production and sales of a product (Bertolini et al., 2006). Studies on traceability systems and approaches for achieving different business objectives have been reported in the literature. The main stream of research on food traceability has been in the area of development of effective traceability systems supported by various product identification technologies (Wilson and Clarke, 1998; Mouseavi et al., 2002; Bertolini et al., 2006; Kelepouris et al., 2007; Peres et al., 2007; Pinto et al., 2007). Some other research (Viaene and Verbeke, 1998; Golan et al., 2004; Schwagele, 2005; Alfaro and Rabade, 2009) concentrates on using traceability information to improve supply chain management. These studies indicated that being able to track and locate products accurately in supply chains can lower inventory levels, quickly detect business difficulties, and improve efficiency of logistics and distribution operations. Among those, Alfaro and

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Rabade (2009) developed a longitudinal case study of a Spanish vegetable company to show how the use of traceability system has provided the company with many qualitative and quantitative advantages along the different stages of their supply chain. Wang and Li (2009a,b) argued that a key issue to add values of traceability to business is to integrate traceability systems with the supply chain management, and use the traceability information to manage and improve business processes. However, quantitative research that identifies benefits of such integration is still rarely found. Among them, Li et al. (2006) proposed a mathematical model for dynamic supply chain planning of perishable foods. The model dynamically allocates products from food processing packaging to distributors, and then from distributors to retailers by using the information provided by a tracking technology which provides dynamic product quality status at each stage of the supply chain.

Another stream of research on food traceability is focused on using operations management approaches to improve traceability management. Bertolini et al. (2006) proposed an application of failure mode effect and criticality analysis methodology to food traceability systems. This enables critical points of risk in the system to be identified, and allows the management to propose improvements for the traceability system by focusing on the most severe situations. Fritz and Schiefer (2009) developed an appropriate tracking and tracing process and decision model. The research analysed the complexity of the multi-dimensional decision situation and identifies tracking and tracing decision alternatives. Dupuy et al. (2005) developed a traceability optimisation model to minimise the recall size by planning batch dispersions in supply chain operations. If a food safety problem comes from a raw material batch, all the finished products containing this raw material have to be identified and recalled. In the food industry, raw materials batches come from different suppliers are often mixed together. This is usually called as batch dispersion problem which concerns all the production process associating disassembling and assembling processes (Dupuy et al., 2005). The research of Dupuy et al. (2005) tried to minimise the impact of manufacturing and delivery processes on the size of possible product re-calls without considering impacts of batch size and dispersion on operations performance. Table 1 summarises the research finding from the above studies.

Determining economic production batch sizes has been of a major interest in both theory and practice. Various optimisation models have been developed (Goyal, 1977; Sarker and Parija, 1994; Sarker and Khan, 1999; Bogaschewsky et al., 2001). A large production batch size reduces the production set-up cost, but increases stock level which leads to high inventory holding cost. Moreover, a large production batch size may require a mixture of raw material batches from different suppliers to fulfil a production order. For perishable food, deterioration and shelf-life have also to be considered to determine an economic production batch size. Dynamic pricing, planning and inventory control models for the perishable food have been reported extensively in the literature. Nahmias (1982) reviewed the literature in ordering policies with both fixed shelf-life perishable inventory and the inventory subject to continuous exponential decay. Goyal and Giri (2001) presented a review of literature for deteriorating inventory models. Other studies were targeting maximum business profits through pricing or allocating perishable products in an operational process according to their fixed shelf-life (Bhattacharjee and Ramesh, 2000; Zhao and Zheng, 2000; Lin and Chen, 2003). In such research, the product shelf-life is a constraint to a pricing or delivery planning decision. Inventory modelling incorporating the effect of a temporary price discount is another active area. Tersine (1994) developed an inventory model which incorporates the effect of a temporary discount in sale price. Shah et al. (2005)

Table 1

Main findings and implications of studies on food traceability.

| Research streams | References | Main findings |
|--|---|--|
| Traceability systems and frameworks | Wilson and Clarke (1998), Jansen Vullers et al. (2003), Kelepouris et al. (2007), Pinto et al. (2007), and Regattieri et al. (2007) | Generic frameworks and guidelines for food traceability implementation; advanced tracking and tracing technologies enabled traceability systems |
| Improve operations management using traceability information | Moe (1998), Li et al. (2006), Wang and Li (2009a,b), and Alfaro and Rabade (2009) | Identify benefits of traceability systems in manufacturing and supply chain management; innovative models of using traceability information to support supply chain decisions; strategic integration of traceability applications and supply chain decisions |
| Improve traceability management using operations management approach | Dupuy et al. (2005), Bertolini et al. (2006), and Fritz and Schiefer (2009) | View the development of traceability system as an optimisation problem; new methodological approaches which enable to perform structured analyses of traceability |

developed a mathematical model for an inventory system that considers a temporary price discount when commodities in an inventory system are subject to deterioration with respect to time.

The above research did not consider traceability related safety factor as an element in manufacturing planning and inventory control. Wang et al. (2009a,b) developed an optimisation model to integrate traceability considerations with operational variables for food manufacturing planning through incorporating operational decision factors with traceability and food shelf-life factors makes integrated decisions for food manufacturers. However, evaluation of food safety in the materials supply which would significantly affect the optimal solution was not considered. Furthermore, the interaction between manufacturers and their customers and its impact on the planning decision were not fully discussed (e.g. financial penalty on food delivery with a lower quality standard).

The research in this paper has proposed an integrated operation–traceability planning model incorporating a risk assessment approach for perishable food supply with the production planning. The impacts of some operational parameters and predicted potential food risk on product recall and operational performance are quantitatively analysed. The research targets the innovation of the production planning strategy through seamlessly integrating food safety and quality issues with operational decisions.

3. An integrated planning model

In this section, the Mixed Integer Non-linear Programming (MINLP) approach is used to formulate the mathematical model of integrated optimisation model. The proposed model involves the choice of raw materials, number and size of batches. MINLP approaches are frequently used for such problems with a clear

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