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Mining logistics data to assure the quality in a sustainable food supply chain: A case in the red wine industry

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ABSTRACT

In recent years, food supply chains have faced increased quality risk, caused by the extended global supply chain and increased consumer demands on quality and safety. Given the concern regarding quality sustainability in the food supply chain, much attention is being paid to continuous planning and monitoring of quality assurance practices in the supply chain network. In this research, we propose a supply chain quality sustainability decision support system (QSDSS), adopting association rule mining and Dempster's rule of combination techniques. The aim of QSDSS is to support managers in food manufacturing firms to define good logistics plans in order to maintain the quality and safety of food products. We conduct a case study of a Hong Kong red wine company in order to illustrate the applicability and effectiveness of QSDSS. Implications of the proposed approach are discussed, and suggestions for future work are outlined.

1. Introduction

Sustainability is one of the most important topics to emerge in recent years (Svensson, 2006; Linton et al., 2007). It encompasses the ideas of lean production and supply chain quality management that are now core to the strategy of most manufacturing firms. Moreover, the development of sustainability provides new ideas to reduce costs, since supply chain management considers the product from initial processing of raw materials to delivery to the customer (Linton et al., 2007). Thus, each operation in different supply chain tiers has the potential to be developed to reduce quality uncertainty, resource waste and operational cost, so minimizing waste.

Supply chain quality assurance represents a continual challenge to supply chain managers in food manufacturing firms. Most companies now include global sourcing as part of their procurement strategy, and the food supply chain usually crosses a number of borders to reach the end user. The severity and complexity of the product quality problem have been aggravated due to the magnitude of the global sourcing issue (Tse and Tan, 2011). Hence, there is a need for research in global food supply chain improvement (Kuo and Chen, 2010). If more members join the supply chain, more uncertainties accrue regarding the quality of the final food product. In such a complicated and multi-layered supply chain environment, firm executives may fail to anticipate the cascading effect that occurs routinely throughout their supply chain operations (Lamarre and Pergier, 2009). In the most serious case, the unsafe product may trigger a product recall that becomes a nightmare for the supply chain members. Another uncertainty factor that influences the effectiveness of product quality assurance is poor visibility in the supply chain (Roth et al., 2008). The dramatic increase in product recalls reveals that those multi-tiered supply chains with low transparency are particularly vulnerable to quality risk (Tse and Tan, 2012).

The intention of this paper is to propose a decision support framework that will reveal possible quality sustainability solutions in food supply chains. The framework will also provide a guide for managers on how to plan a logistics solution to assure the quality of food products in a distribution network. The paper develops a decision support model for supply chain quality sustainability (hereafter QSDSS) based on the association rule mining and Dempster's rule of combination. The RFID technology (Mo et al., 2009) is adopted in the proposed DSS to monitor and capture quality data, and association rule techniques are employed to data mine the good logistics plans used to transport food products in the distribution network, so as to reduce uncertainty and manage risk in the supply chain. In the proposed method, the first stage recognizes associations between logistics order flows (such as Factory A to Distributor B) and source to source relationships (such as mode of transportation, type of product, delivery period) by using association rule mining. In the second stage, an aggregation method is used to group interesting rules (discovered in association rule mining) for particular order flows with quality assurance settings by using Dempster's rule of combination. In order to test the validity of the proposed DSS, a case study is conducted with a Hong Kong red wine company, and its test results are evaluated by a focus group of academics and industrialists.

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The remainder of this paper is organized as follows: Section 2 comprises a literature review. Section 3 describes the proposed QSDSS framework. Section 4 describes the case study of a Hong Kong red wine firm. Section 5 presents the discussion and managerial implications. Finally, in Section 6, conclusions are presented, along with summaries and guidelines for effective quality assurance in the red wine supply chain.

2. Related studies

2.1. Quality sustainability in the food supply chain

The food supply chain is defined as "the total supply process from agricultural production, harvest or slaughter, through primary production and/or manufacturing, to storage and distribution to retail sale or use in catering and by consumers" (Kuo and Chen, 2010).

Over the last decade, the increase in the number of food-borne pathogens and poisoning has altered the demands on and characteristics of the food supply chain (Lao et al., 2012; Henson et al., 1999; Unnevehr and Jensen, 1999). Quality assurance in the food supply chain is becoming more and more important, as it is necessary to satisfy customer needs that are directly related to social responsibility (Roth et al., 2008; Tse and Tan, 2012; Lao et al., 2012).

Food supply chain management requires caution and a strategic handling process, since improper handling practice can result in serious consequences, such as food poisoning and product recall. Therefore, the food supply chain requires a well-planned quality assurance practice in order to avoid the occurrence of quality risk (Tse and Tan, 2012; Tse et al., 2011). To control product quality to the fullest extent, it is necessary to ensure the proper quality sustainability of logistics operations in all supply chain entities. In a study of cold supply chain tracking, Montanari (2008) points out that the integrity of the food supply chain must be preserved from the point of production and processing, to storage at the consuming household or restaurant. Lao et al. (2012) argue that adoption of cautionary quality control in upstream supply chain members is imperative, particularly in the distribution centers. Van Der Vorst et al. (2009) state that in order to respond effectively to changes in quality and the environment, redesign of the entire food supply chain is vital. They further note that the design of the food supply chain has become complicated due to an intrinsic focus on product quality which is directly associated with integrity and safety. According to Svensson (2006), sustainable quality assurance practices should be adopted within a circulation approach, so as to create a chain and a series of business operations without loose ends.

Van Donselaar et al. (2006) and Van Der Vorst et al., (2009) argue that food supply chain sustainability is not limited to quality assurance, but also implies the reduction of food waste, whereby food products have to be disposed of because they have deteriorated. Kleijnen and Vorst (2005) state that the fundamental causes of waste in food supply chains are product quality deterioration and lack of supply chain coordination. In order to obtain quality sustainability, a redesign of supply chains and the adoption of tracking technology (such as RFID) are required. Montanari (2008) notes that each transport phase (e.g. loading, unloading, handling, and storage) in a food supply chain plays an important role in achieving the quality sustainability. Also, potential quality threats may result from the size of shipments, reliability of equipment, and ownership transfer of products moving through the transportation network. In addition, Kuo and Chen (2010), Hsu and Liu (2011) and Montanari (2008) stress the importance of temperature control of logistics movement and storage of food products in the cold supply chain for maintaining the original value and quality. Moreover, keeping track of the temperature conditions therein can identify the potential quality risk, the shelf life and final quality of chilled products.

2.2. Data mining association rule

Data mining is the process of finding the patterns, associations or relationships among data using various analytical techniques and involving the creation of a model, so that the concluded result will become useful information or knowledge. Association rule mining is one of the most popular data mining techniques in formulating decision support systems (Ting et al., 2012, 2010a; Chien and Chen, 2008; García et al., 2008). It aims to extract interesting correlations, frequent patterns, associations or causal structures among sets of items in databases (Kotsiantis and Kanellopoulos, 2006). A famous example of applying association rules is market basket analysis (Chen et al., 1996). Agrawal and Strikant (1994) introduce the Apriori algorithm for discovering regularities between products in large scale transaction data recorded by point-of-sale systems. The rules can be expressed as "$\{X, Y\} \rightarrow \{Z\}$ [support: 60% and confidence: 80%]" meaning that X, Y and Z occur in 60% of all transactions (i.e. support) and 80% of the transactions containing X and Y contain Z (i.e. confidence). In general, a rule is regarded as interesting if it satisfies the minimal thresholds for both support and confidence predefined by experienced users or domain experts.

Association rule mining is now widely adopted in decision support systems (DSS) in industrial and logistics applications. Ketikidis et al. (2008) develop an association rule DSS to provide decision support in material sourcing, production scheduling and physical distribution. Lau et al. (2009) develop a process mining DSS for identifying the root causes of quality problems in a supply chain, and for providing some configuration parameters to fine tune the operational process to improve the performance. Liao et al. (2008) propose an association rule DSS to develop product maps for new product development. Their DSS aim to investigate the relationships among customer demands, product characteristics, and transaction records in order to discover different knowledge patterns and rules from customers so as to develop new cosmetic products and possible marketing solutions. Tsai et al. (2009) adopt an association clustering technique to mine the correlated demands, and then to establish a joint replenishment policy, which significantly reduces the operational cost. Their proposed algorithm employs the "support concept" in association rule analysis to measure the similarity of different products. Hsieh and Huang (2010) propose a heuristics approach in order to provide an order picking system in a warehouse, where an association rule clustering analysis is used to find the highest relativity of different items in the same order picking batch. Similarly, Chen and Wu (2005) adopt an association rule clustering analysis to discover the associations between orders. The customer demand pattern is identified by discovering hidden rules, such as when the occurrence of some orders in a batch may also have the occurrence of other orders in the same batch.

There are a number of association rule DSSs aimed at streamlining integrated warehouse operations, such as order picking. There have been relatively few attempts at formulating a DSS for conducting data analysis from the upstream to downstream supply chain (Tse et al., 2009; Lau et al., 2009). However, operations in different supply chain members are closely related to each other, and tiny changes in each operation may generate a significant difference in the other mined rules (Kim, 2007). Thus, if one concentrates attention on only one particular supply chain tier, he may fail to obtain the effective association rules in the entire distribution network, since the attributes of the associate