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A knowledge-based logistics operations planning system for mitigating risk in warehouse order fulfillment

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ABSTRACT

Customer orders with high product varieties in small quantities are often received by the logistics service providers with requests for customized value-added services and timely delivery, so the warehouse has to plan its logistics strategy in such a way that it can effectively maintain the quality of its services. In addition, they have to pay attention to the possible risks that may occur during the logistics operations so as to prevent loss if they fail to deal with the problems and risks properly. In order to facilitate the decision making process in warehouse operations, an intelligent system, namely the knowledge-based logistics operations planning system (K-LOPS), is proposed to formulate a useful action plan by considering the potential risks faced by the logistics service providers. The system makes use of Radio Frequency Identification technology to collect real-time logistics data. Analytical hierarchy processes and case-based reasoning are integrated into the system. These help to categorize the potential risk factors considered by customers and formulate the logistics operations strategy, respectively, as the different product characteristics and order demands are taken into consideration. The searching performance in case-based reasoning is enhanced by the iterative dynamic partitional clustering algorithm. After conducting a trial run in the case company, the result shows that there is significant improvement in case retrieval time and in solution formulation.

1. Introduction

In order to survive in today's highly competitive business environment, the function of the warehouse in a supply chain is no longer only to keep a large amount of stock in storage. Instead, customer orders with high product varieties in small quantities are often received by the logistics service providers (LSPs), with requests for customized value-added services and timely delivery. Since the decision making process is one of the most complicated processes involved in warehouse operation, the fulfillment of customer orders in the warehouse is challenging as it is necessary to satisfy increasing customer demand in terms of responsiveness, cost effectiveness and flexibility. In addition, due to the uncertainty and rapid changes in the business environment, the performance of warehouse operations is not only affected by the logistics strategy planning process, but also by the possible risks that may occur during the logistics operations. Thus, attention should be paid to establishing a knowledge-based decision support system to support the planning of responsive logistics strategies that can be formulated to fulfill the demand of high efficiency and quality in logistics service requirements. However, only a small number of research studies are reported to have taken risk control into consideration during the decision making process in the area of warehouse operations.

As the company is required to handle a large number of orders for diversified products, making a wrong decision in the logistics operations would affect the warehouse performance and the quality of customer service. Current order fulfillment decisions are made based on the knowledge of the warehouse manager. It is difficult for the warehouse manager to give appropriate order handling instructions with consideration of the product characteristics and existing warehouse operations. Bias and subjective judgment may result in an inaccurate decision. The lack of a resources allocation strategy may mean that no suggestions regarding the allocation of resources are provided on how to handle the order when a possible risk occurs. This might result in improper use of resources and loss of customer satisfaction.

The aim of this research is to propose and develop a knowledge-based logistics operations planning system (K-LOPS) so as to support the decision making process in planning and controlling warehouse operations. K-LOPS makes use of Radio Frequency Identification (RFID) technology and artificial intelligence techniques, i.e. analytical hierarchy process (AHP) and case-based reasoning (CBR), to collect real-time warehouse data and relevant logistics data for providing knowledge support in decision making when

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operational problems occur. Considerable risks of concern to the customer regarding the product characteristics are identified and become key factors during the planning process of warehouse operations. Due to the necessity to search for similar and useful cases from past explicit knowledge, a newly-designed algorithm, namely the iterative dynamic partitional clustering algorithm (iDPC), is integrated into the CBR engine to improve the performance in retrieving past similar cases. This paper is organized as follows. In Section 2, the literature related to risk and warehouse management, RFID, AHP and CBR technique is studied. Section 3 presents the system architecture of K-LOPS. In Section 4, a case study is presented to demonstrate the implementation procedures of the system. In Section 5, the results of implementing the system are discussed and a conclusion is drawn in Section 6.

2. Literature review

2.1. Warehouse operations and risk management

Risk is defined as an exposure to the possibility of negative economic impact, physical damage or delay as a consequence of the uncertainty associated with the action performed (Chapman and Cooper, 1983; Jüttner et al., 2003). Risk taking is regarded as an integral and inevitable part of management in a business (Zsidisin and Ritchie, 2008). Svensson (2002) mentioned that risk management is able to improve competitiveness, reduce costs and maintain profitability. Lubka (2002) also indicated that risk management acts as a way to help the company in achieving its goals. In general, risk management in the supply chain refers to the concept of Supply Chain Risk Management (SCRM), which would be beneficial to the parties involved in terms of cost reduction and increase in profitability. SCRM refers to the management of supply chain risks through coordination or collaboration among the supply chain partners for the purpose of profitability and continuity (Tang, 2006; Manuj and Mentzer, 2008). Due to the complex network in the supply chain, it is more risky to work with a number of firms to improve the financial performance and competitive advantages (Hauser, 2003). According to ISO 31000, risk management consists of three steps: (i) identification, (ii) assessment, and (iii) prioritization of risks, that aim at minimizing, monitoring and controlling the probability and impact of unfortunate events (Carole and Olivier, 2012). Responses are given to mitigate the effect of or prevent the occurrence of risk.

The warehouse operations involve a number of processes which increase the complexity of effective planning. Depending on the type of warehouse and product to be handled, the attention paid and the customer requirements are also different. Warehouses handling general cargo may focus on the efficiency of order fulfillment, while providing good quality control is important for a warehouse where special goods that are sensitive to temperature are handled. Thus, product characteristics may sometimes impose constraints and uncertainties on warehouse operations planning. Concerning sustainable development of a business, it is very important to implement risk management that assesses risks faced by the organization and develop contingency plans to mitigate the consequences of risks and assure continuity of risk management in an organization (Pai et al., 2003). Most of the literature emphasizes the importance of risk management in terms of advantages. According to Kaplan et al. (2001), risk can be represented in a quantitative way by considering the relativity of risk, and acceptability of risk. To deal with the concept of risk management in an organization, it is ineffective that the company only uses implicit knowledge and experience for risk management. This is because those assessing the risk may lack sensitivity when estimating the probability of possible outcomes induced by the risks. In some cases, an organization may tend to focus on critical performance rather than risk outcomes. Therefore, it is very important for a company to adopt a risk management model and approach with a quantitative model and qualitative plans to assess risks.

2.2. Artificial intelligence techniques in decision support

The analytical hierarchy process (AHP) is a flexible approach that allows subjective factors to be considered in risk analysis. It integrates multi-criteria decision-making methodology with both quantitative and qualitative criteria (Gerdsri and Kocaoglu, 2007). It is important that the hierarchy should be clearly constructed because different complexities of the hierarchy result in different rankings (Ishizaka and Labib, 2011). With the developed hierarchy, the company can compare and determine the relative importance of options (Dey, 2001). Pair-wise comparison starts from the second level and ends in the lowest hierarchy level. Criteria are then paired up and evaluated based on the designated scale. Zayed and Pan (2008) used AHP to determine the weights of risk areas in a Chinese highway project in which a higher weighting value resulted in higher importance of the option. Chan and Kumar (2007) proposed a fuzzy extended analytic hierarchy process (FEAHP) approach in a global supplier selection problem. In the study, the critical decision criteria including cost, quality, service performance and supplier's profile with the risk factors for the development of an efficient system were considered. Wang et al. (2008a) proposed an integrated AHP–DEA approach to evaluate the risks of bridge structures so as to determine the maintenance priorities of the bridge. To sum up, AHP is able to assess the defined alternatives effectively, based on various decision support criteria by conducting pair-wise comparisons. Therefore, it is useful to prioritize risk factors in a systematic way when making use of the quantitative approach which can increase the accuracy of the assessment.

Case-based reasoning (CBR) is one of the well-known knowledge repository and learning techniques that are widely adopted in decision making based on previous experience. It makes use of a similar previous experience to provide decision support to a new problem instead of an intuitive estimation approach (Wang et al., 2008b). By using CBR, the solution obtained in a past case is expected to be useful in solving a new problem (Craw et al., 2006). The CBR cycle comprises four processes: retrieve, reuse, revise and retain where case retrieval is an important step to search for appropriate similar cases (Aamodt and Plaza, 1994). Clustering is one of the retrieval methods that can reduce searching time by grouping the related information into the same cluster (Kang et al., 2007). With the use of the clustering approach, the performance of the retrieving process is increased in terms of time, efficiency and effectiveness (Can et al., 2004). Given that the clustering result is sensitive to initial centers, the Genetic Algorithm (GA) has been suggested by Laszlo and Mukherjee (2007) in searching for the cluster center of the *k*-means clustering algorithm, which allows a near-optimal cluster result to be produced. The results show that the GA *k*-means clustering method can improve segmentation performance compared with other typical clustering algorithms (Kim and Ahn, 2008).

2.3. Automatic data capturing technologies

Furthermore, to enhance the speed and accuracy of information sharing, automatic data capturing technologies are required to increase the visibility of the operation. Two commonly used data capturing technologies in use today, i.e. the bar-code system and the Radio Frequency Identification (RFID) system, are introduced. In the last decade, the barcode was a popular technology that was widely adopted in the areas of retail, logistics, warehousing and

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