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A customer satisfaction inventory model for supply chain integration

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ABSTRACT

Customer relationship is increasingly influencing the performance of inventory management in a supply chain, and customer retention or migration directly affect the number of customer orders and demands as well as the inventory level. Therefore, the aim of this paper is to propose a customer satisfaction inventory (*CSI*) model that incorporates customer relationship management into an inventory model, where the probabilistic concepts of Markov chains of uncertainties in customer relationships of retention or migration are adopted. This enables us to determine both a *CSI level* for replenishing the inventory level to best fit future customer demand and a customer *CSI value* of the net profit or loss of an organization from a customer over its purchasing life against the inventory cost of an organization. The modeling and development of the proposed customer satisfaction inventory *CSI* model are discussed in this paper. Simulation and analysis are conducted for the proposed model, and satisfactory results are achieved, such that the proposed model can help to determine a *CSI level* that can fully meet orders and demand as well as minimizing inventory cost and maximizing *CSI value*.

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1. Introduction

Inventory management and customer relationship management are two co-related aspects in a supply chain, where customer relationship increasingly influences the performance of inventory management (Silver, 1981; Swink, Narasimhan, & Wang, 2007). The tendency of a customer's retention or migration can directly affect the number of customer orders and demands as well as the inventory level in a supply chain (Sramek, Mentzer, & Stank, 2008; Zhu & Thonemann, 2004). Information, including marketing strategy or sales demand etc. (Wang, Lau, & Lau, 2008) should also be shared within a supply chain. Among various expenditures in a supply chain, inventory costs generally account for the majority. Therefore, minimizing the inventory cost is a major objective in a supply chain, and it is widely accepted that keeping excessive stock is costly and ineffective (Aggawal, 1974).

During the past few decades, various literatures and models have been published and proposed for effective inventory management (Axsater, 2006; Bartmann & Beckmann, 1992; Lewis, 1997; Lu, Song, & Zhu, 2005; Pfohl, Cullmann, & Stolzle, 1999; Watts, Hahn, & Sohn, 1994; Xiong & Helo, 2006; Yung, Ip, & Wang, 2007), for example the Economic Order Quantity Model, RM-System, Newsvendor Problem, AHM Model, Bisection Method, etc. However, most of these inventory management models only account independently for various demand patterns, quantity discount, stockout costs, lead time variations, multi-stage/multi-item situations, etc., but few concepts or models are suggested for incorporating the customer relationship into the inventory management model. Therefore, in this paper, a customer satisfaction inventory *CSI* model is proposed for the supply chain. This is an integrated model that incorporates the probabilistic concepts of Markov chains of uncertainties in customer relationships of retention or migration into an inventory model, such that the customer loyalty towards a supply chain becomes a decision variable in the inventory management, and customer relationship management and inventory management can then be integrated in the supply chain. Supply chain integration can enhance the overall supply chain performance (Fuentea, Rosa, and Cardo, 2008; Lam, Chan, Ip, & Lau, 2008; Lam, Ip, & Lau, 2009). More importantly, customer loyalty and retention play a vital role in a supply chain, as acquisition costs considerably exceed retention costs (Bloomberg, 2001; Dyche, 2002), and loyal customers with a long-standing relationship with the supply chain will make regular repeat purchases, thereby facilitating a gain in long-term profits (Chan & Ip, 2008; Ip, Chen, Lau, Choy, & Chan, 2008).

The Markov chains model is a probabilistic model accounting for the uncertainties in customer relationships. It uses probability and expected value to measure future relationships with an individual customer. The concepts of Markov chains are capable of modeling customer relationships and supporting business decision making for business growth, features that are in high demand in the disciplines of marketing and customer relationships (Bornnenberg, 1998; Chen, Ip, & Sheng, 2005; Lu & Jiang, 2004). It has been claimed that the major advantages of the Markov chain model are

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its flexibility and sophistication (Isaacson and Madsen, 1976; Puterman, 1994). Markov chains make use of a series of states of a system or process to identify all possible conditions; a Markov chains model of purchases states for a customer relationship (Pfeifer and Carraway, 2000) is shown in Fig. 1. It has a wide range of Markov properties, including reducibility, periodicity, recurrence, ergodicity, steady-state analysis, and limited distribution for precise prediction. Markov chains modeling can handle customer retention and customer migration situations, and can apply either to an existing customer or to a prospective customer. Therefore, by incorporating Markov chains into the inventory model, customer relationships of retention and migration can be analyzed and evaluated in the inventory management of the supply chain.

The structure of this paper is as follows: in Section 2, the proposed customer satisfaction inventory *CSI* model is defined and modeled, and the assumptions and algorithms for the modeling are presented. In Section 3, a decision support system is developed to illustrate the effect of the proposed *CSI model*, datasets are collected and analyzed, and the empirical analysis results are presented afterward. Finally, a conclusion with further developments is given in Section 4.

2. Development of the customer satisfaction inventory *CSI* model

The proposed customer satisfaction inventory *CSI* model is an integrated model that incorporates the probabilistic concepts of Markov chains of uncertainties in customer relationships of retention or migration into an inventory model, such that the customer loyalty towards a supply chain becomes a decision variable in the inventory management as well as in the determination of a customer satisfaction inventory level (*CSI level)* and a customer satisfaction inventory value (*CSI value)* for the model. Therefore, the proposed *CSI model* is an integrated model that is a function of *CSI level* and *CSI value*.

In the *CSI model*, the *CSI level* is a utility function that represents a deterministic inventory level based on the probabilistic customer relationship of retention or migration, such that the replenishment inventory level can be better tailored to future customer demand without keeping excessive inventory. The *CSI value* is another utility function that represents a value of the net profit or loss of an organization from a customer over its purchasing life against the inventory cost of an organization, such that this value is also governed by the probabilistic customer relationship of retention or migration as well as the inventory cost of setup cost, backorder cost, and inventory holding cost.

For the development of the *CSI model*, customer satisfaction directly affects the customer relationship of retention or migration, therefore, a set of Markov chains stating *state* = $\{s_1, s_2, \ldots, s_t\}$ is defined for the state of customer retention/migration, with transition probability p at time $t = 1, \ldots, t$, such that if chain state s_i is currently at $t = i$, then it will have a transition probability $P = p_{ij}$ that the chain state moves to state s_j at $t = j$, where the transition probability is a customer retention probability (p_{ij}) or customer migration probability ($1 - p_{ij}$). The customer retention probability determines the degree of likelihood that a customer will repurchase in a supply chain, while the customer migration probability determines the degree of likelihood that a customer will terminate the order in the next time state. A schematic diagram for the probabilistic concepts of Markov chains in inventory management is illustrated in Fig. 2.

Considering the diagram in Fig. 2, if a customer at state s_1 purchases from a supply chain, then the customer retention probability for repurchase in the next time stage s_2 is p_{12}, while the customer migration probability for purchase termination is p_2:

$$P = \begin{bmatrix} p_1 & 1-p_1 & 0 & 0 & 0 & 0 & 0 & 0 \\ p_2 & 0 & 1-p_2 & 0 & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ p_i & 0 & 0 & 0 & 1-p_i & 0 & 0 & 0 \\ p_j & 0 & 0 & 0 & 0 & 1-p_j & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ p_{t-1} & 0 & 0 & 0 & 0 & 0 & 0 & 1-p_{t-1} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}.$$

The above transition probability matrix summarizes the transition probabilities shown in Fig. 2. Matrix P is the one-step transition matrix. To evaluate customer purchase probability over t period, a *t-step* transition matrix is used. The *t-step* transition matrix is simply the matrix multiplication product of t one-step transition matrices. With the transition probability p_{ij} of the customer retention in a set of Markov chain states, the *CSI level* in the proposed model with respect to its maximum inventory level *MAX* and minimum inventory level *MIN* at time $t = j$ is defined as

$$CSI\ level_j = \left[MAX - \left(CSI\ level_i + S_j - D_j\right)\right] \times p_{ij} \quad \text{for} \quad \left(CSI\ level_i + S_j - D_j\right) < MIN, \tag{1}$$

where S is the inventory supply while D is the customer demand, and p_{ij} is the transition probability, which is further defined as

$$p_{ij} = \begin{cases} 1, & P(\text{retention}) \geqslant P(\text{migration}); \\ p_{ij}, & \text{otherwise} \end{cases} \tag{2}$$

Therefore, with the *CSI level*, the setup cost, backorder cost, and inventory holding cost can be determined. The setup cost is the cost for setting up an order to fulfill a demand or to replenish the inventory, and it is directly related to the order frequency, so the setup cost A at time $t = j$ with respect to its previous reference setup cost, and the expected setup rate is defined as

$$A_j = A_i \times \frac{(D_1 + D_2 + \cdots + D_j)}{CSI\ level_j}. \tag{3}$$

Backorder cost is the cost for each demand unfilled and for its backordered time, i.e. the supply from the inventory level cannot fulfill

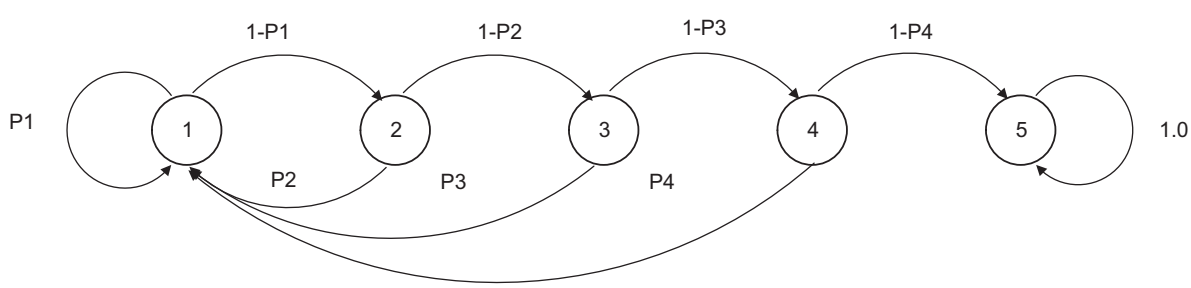

Fig. 1. Markov chains model of purchasing states for customer relationship.

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