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A real-time inventory model to manage variance of demand for decreasing inventory holding cost

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ABSTRACT

Variance of demand is one of the inevitable problems in the manufacturing environment. Market conditions and competition force companies reducing costs. Different approaches and methods have been developed to remedy these problems. Common points of these approaches are utilizing resources and responding in the shortest time possible. To achieve better inventory management, inventory-holding cost is tried to be decreased under the same service level. Re-order point is arranged dynamically regarding couple of factors in some studies. We try to arrange the re-order point in a time based manner by transforming the re-order point into re-order time, which eliminates the safety stock; and it makes the inventory model real-time.

Recent production planning studies focus on real-time planning and dynamic scheduling to increase utilization and robustness. In these studies, real-time data is used for planning, but in most of them manufacturing systems and planning methodology are not transformed into a real-time system approach. The novel aspect of this study is the presentation of a model in which the manufacturing system has been designed as a real-time system that consists of real-time planning activities working with real-time data, and eliminating the safety stock.

1. Introduction

Increasing variance of demand causes businesses to hold more inventory. Re-order point model offers safety stock against the variance of demand, which causes additional inventory holding cost. However, while competition obliges companies to decrease costs and move faster, product variety is increasing to adapt to changes in the market. Achieving rapid response times by holding inventory is inefficient, while decreasing lead-time is efficient. Thus, agile manufacturing, adaptive manufacturing, and lean manufacturing studies focus on solving utilization and lead-time problems. In light of this, we aim to develop a planning methodology that enhances planning strategy precise against time dependent changes.

In current approaches, attempts are made to overcome variance of demand through holding safety stock and alternative strategies. Yet these strategies (utilizing multiple suppliers, just-in-time manufacturing and so forth) require significant infrastructure investment and cause additional costs. Instead of applying classic strategies or variations of them, we designed a model that allows the planning process to begin as early as possible, avoiding safety stock. This early planning approach eliminates safety stock by setting the time at the order given, which is the difference between proposed model and re-order point. To set the order time, inventory depletion time is calculated on every inventory transaction. When calculated time is equal to supply lead-time, then the supply order is given.

Time based planning of inventory, makes the approach real-time, in order to make it amount based, because real-time systems are systems working under time constraints to achieve time goals (Zhang, 2010). Real-time systems must provide responses within a set timeframe, as Paul et al. explain (Paul, Sarker, & Essam, 2015). Proposed method provides the time window to be calculated for giving an order, which is the significant point making the model a real-time system.

Real-time systems are divided into two categories: hard real-time systems break down when any failure occurs, while soft real-time systems carry on when any failure occurs. Failure can be incorrect output or any output produced after the time allowed expires. Our model is a soft real-time system, as the model can be run under stock out conditions and with extra inventory holding cost related to variations of demand in a particular period.

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2. Literature review

Various strategies have been developed and adapted to the manufacturing environment to manage uncertainty, which is one of the inevitable problems in the manufacturing environment. The uncertainty problem is investigated by studying the variance of orders, variance of lead-time and backorder (Chatfield & Pritchard, 2013; Sodhi, Sodhi, & Tang, 2014). Lee et al. recommend the application of order batching, considering order trends, and sharing information to lessen the bullwhip effect and decrease costs (Lee, Padmanbhan, & Whang, 1997). Information sharing lowers cost and manufacturing lead-time by decreasing uncertainty, as Lee et al. show in the two-level supply chain (Lee, So, & Tang, 2000). However, it does not decrease the complexity of manufacturing and is invalid in some cases.

According to Xu et al., when market conditions become volatile, companies should decrease product modularity (Xu, Lu, & Li, 2012), which can be overcome by implementing a robust manufacturing system. Moreover, people attempt to manage manufacturing complexity with dynamic systems; dynamic routing in a just-in-time system is one of the obvious examples of this (Emde & Boysen, 2012; Weng, Wei, & Fujimura, 2012). Georgiadis and Michaloudis studied the dynamic adaptation of a desired system's states in a similar manner (Georgiadis & Michaloudis, 2012), whereas Prince and Key applied group technology via virtual groups to be independent of layout to provide the manufacturing system's agile and lean production characteristics (Prince & Kay, 2003). With group technology, the manufacturing schedule is not affected by changing the manufacturing order in-group when an unexpected situation occurs (Ji, Chen, Ge, & Cheng, 2014).

Variance of inventory is tried to be controlled via different lot sizing and re-order point strategies in the literature. Chen tried to find the optimal re-order point and lot size by fuzzy membership functions, dynamically (Chen, 2011). Babai et al. focused on forecast based dynamic re-order point control policy to reduce computation time and inventory holding cost (Babaı, Syntetosa, Dallery, & Nikolopoulos, 2009). Porras and Dekker implemented a bootstrap method to re-order point model to decrease inventory-holding cost, which they modify (Porras & Dekker, 2008). Gamberinia et al. analyzed different re-order policies and inventory management approaches under irregular and sporadic demand profiles, because assuming current techniques are not simply enough and effectively implementable for different manufacturing environments (Anonymous, 2014). These studies show that dynamic re-order point decreases the inventory holding cost under same service level.

One way of changing re-order point is making the inventory management inventory Zhong et al. noted that the real–time monitoring of manufacturing decreases tardiness and increases the immune ability (Zhong et al., 2015). In addition, Hung et al. showed that planning with real-time data decreases lead-time (Hung, Huang, & Yeh, 2013). Real-time production planning studies generally focus on collecting real-time data from job shops. Thus, Poon et al., Choi and Shin, and Zhang et al. use real-time data to set the current state of the system as the time at which planning begins (Choi & Shin, 1997; Poon et al., 2011; Zhang, Huang, Sun, & Yang, 2014). According to Cowling and Johansson, dynamic scheduling with real-time data increases stability and utility (Cowling & Johansson, 2002).

Real-time systems are generally applied in emergency processes (Jeong, Han, Song, & Yeo, 2010), earthquake monitoring (Brown et al., 2011), or chemical processes (Zuo & Wu, 2000) that require instant (in a particular time) reaction or response. However, because studies focus on working with real-time data, manufacturing systems usually are not designed as real-time systems. Real-time data is used for planning in a classic system with classic approaches. This study will contribute the literature by a real-time inventory planning approach and eliminating safety stock.

3. Real-time inventory model

Real-time inventory model transforms current inventory planning approach into a time driven perspective, and eliminates the safety stock in its manner. As the time to depletion of remaining inventory, reorder time (ROT) is used in the real-time inventory model instead of reorder point (ROP), as is the case in the current approach. ROT is a particular time, making the system real-time, changes constantly when any variations of demand occur. Eventually, safety stock is unneeded in the real-time inventory model. However, the variance of orders is handled with safety stock in the re-order point model. This significant difference of real-time inventory model eliminates the additional inventory holding cost by eliminating safety stock.

Two inventory models are compared in three cases to investigate the effect of eliminating safety stock in the real-time perspective. The first case is to satisfy all orders with the exact amount of inventory (including safety stock), the second is to satisfy all orders with some inventory left over, and the third case is a stock out. The three cases are designed to represent all situations in inventory management process, which can be faced with. The average inventory holding cost is investigated as a domain to compare both models, because the order points can be different as time and amount. On the other hand, inventory holding cost is a common performance factor for inventory models. Different types of service levels are not considered in this study, although they are common factors.

Orders are given at ROT in the real-time model and at ROP in the current approach, in which safety stock is used, as shown in Fig. 1. Because all inventory is consumed in the period regarding to the first case, all safety stock (Q_S) is considered as sold. New inventory is assumed to arrive when inventory is consumed.

Inventory holding cost is equal to the product of the area in the chart and unit variable cost (C_V), with multiplication of the unit constant cost of warehousing (C_C) and the cycle time (L_O in the real-time model, L in the re-order point model). The initial inventory amount is Q, the total inventory holding cost is C_T, and the average inventory holding cost is C_A.

$$C_T = L_O C_C + \frac{Q C_V L_O}{2} => C_A = \frac{C_T}{L_O} = C_C + \frac{Q C_V}{2} \quad (1)$$

The initial amount of inventory in the re-order point model is $Q + Q_S$ because of the safety stock. The amount of Q inventory is consumed during L_O, and safety stock is consumed during $L - L_O$. C_T and C_A are provided below for the re-order point model.

$$C_T = L C_C + \frac{(Q + Q_S) C_V L}{2} => C_A = \frac{C_T}{L} = C_C + \frac{(Q + Q_S) C_V}{2} \quad (2)$$

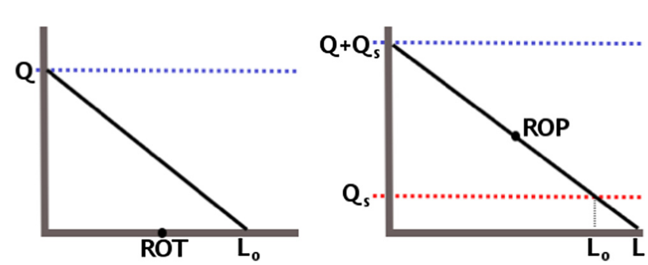

Fig. 1. Reorder time and reorder point (the first case).