Chapter 73
Discrete Event Simulation in Inventory Management

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ABSTRACT

Perishability and substitutability are two key attributes that cannot be ignored in supply chain management. Once produced, perishable products have a finite shelf life. When expired, they are either partially or wholly value-less. The more time that perishable inventory is in storage, the less time it is available for sale to customers. Product substitution is a possibility when considering multiple products. Research indicates that an alternative product is willingly chosen by customers if the preferred one is out of stock. Managers must decide on the replenishment time and replenishment quantity for each item within product subcategory to maximize expected profits under uncertain demand while minimizing the instances of running out of inventory (i.e., a stock out). The combination of these factors often requires simulation models to be developed to understand the behavior of the system as the parameters change. Simulation can incorporate stochasticity and complexity while providing detailed output for further analysis and optimization work.

INTRODUCTION

Successful supply chain management aims to deliver the right products at the right time to the right place and in the right condition (Deniz, Scheller-Wolf, & Karaesmen, 2004). This is not a simple task, and many factors influence the success of the supply chain; perishability and substitutability characteristics of inventory are key attributes that cannot be ignored. Once produced, perishable products have a finite shelf life. When expired, they are either partially or wholly value-less. Perishability affects many industries (e.g., fresh food and chemicals). The more time that perishable inventory is in storage, the less time it is available for sale to customers. The combination of these factors often requires simulation models to be developed to understand the behavior of the system as the parameters change.

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Product substitution is a possibility when considering multiple products. Research indicates that an alternative product is willingly chosen by customers if the preferred one is out of stock, and product substitution is important to companies (Chen, Feng, Keblis, & Xu, 2015). Research shows that consumer-driven substitution due to product stock-outs common in the grocery industry (Bijvank & Vis, 2011). In a recent study, the Grocery Manufacturers of America estimated that approximately 70% of consumers who find a particular item is stocked out on the first occurrence will happily purchase another product (Grocery Manufacturers Association, 2015). van Donselaar, Van Woensel, Broekmeulen, and Fransoo (2006) analyzed these types of situations and suggested that accounting for substitution while establishing inventory control policies could lead to a reduction in waste.

Holding inventory is necessary for a firm to fulfill customer orders; however, holding inventory also incurs holding cost (e.g., providing material storage and insurance). Each product has a holding cost applied to the average inventory level over a specified period, a selling price, and a cost per unit of stock. Managers must decide on the replenishment time and replenishment quantity for each item within product subcategory, to maximize expected profits under uncertain demand while minimizing the instances of running out of inventory (i.e., a 'stock out').

Determining the appropriate replenishment policy that will maximize profit under probabilistic consumer demand is known as stochastic optimization. In stochastic situations, it becomes difficult to formulate models accommodating so many factors. According to Lucas, Kelton, Sánchez, Sanchez, and Anderson (2015), a discrete-event simulation methodology is suitable to capture the dynamics of this problem. Discrete-event simulation involves modeling a system and where a specific event triggers a change in the state of the system. Such simulation allows tracking of specific items of inventory (e.g., when an item 'expires' it would trigger an event and a change in the system state); this is a necessary precondition that makes this type of simulation more appropriate than continuous simulation for the modeling of substitutable and perishable inventory systems. Such simulations can also be used in the evaluation of new IT improvements that can be used to improve collaboration practices over the supply chain (Cannella, Framinan, & Barbosa-Póvoa, 2014). Simulation can incorporate stochasticity and complexity while providing detailed output for further analysis and optimization work.

BACKGROUND

In general, there are four types of perishable products: food items (e.g., meat, vegetables, dairy products, and beverages), medical/pharmaceuticals (e.g., vaccines, blood, and drugs), plants, and industrial/other (e.g., paint and chemicals). Each type may have several categories, subcategories, and product variants. For example, milk products can be divided into powdered milk or ready-to-drink milk products. Ready-to-drink milk products can be further divided into yogurt or drinks; then, by flavors and sizes.

Managers must decide the inventory level for perishable products to ensure customers have all desired products at the right time at minimal disposal cost. Managers want to provide the highest customer service level at the lowest cost. Some of these costs that play a significant role in perishable inventory management include ordering cost, holding cost, disposal cost and shortage/backlog cost. Nahmias (2011) gave a comprehensive review of the perishable inventory theory. There is two primary inventory management approaches, periodic review (monitoring inventory levels at fixed intervals) and continuous review (monitoring inventory levels continually). Periodic review has been widely used for a long time due to the relative simplicity of application; it involves the amount of inventory at a particular

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