Simulation to Improve Management of Perishable and Substitutable Inventory

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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. A crucial element that remains difficult to manage is the perishability and substitutability - these attributes cannot be ignored. Once produced, perishable products have finite shelf life. When expired, they are either partially or completely 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.

Product substitution is a possibility when considering management of multiple products. Research indicates that an alternative product is willingly chosen by customers if the preferred one is out of stock (Myers, 2009). Research shows that consumer-driven substitution due to product stock outs are common in the grocery industry (Myers, 2009). In a recent study, the Grocery Manufacturers of America estimated that approximately 60% of consumers who find a particular item is stocked out will happily purchase a substitute product from the same store (Kraiselburd, Narayanan, & Raman, 2004). 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. However, Van Donselaar et al., (2006) also highlighted that further investigation is required to determine the best policies for such a multi-product, multi-expiration date environment that will also account for items substitution.

Holding inventory is important for a firm as it allows the firm to fulfill orders for a customer. However, holding inventory also incurs a cost - an inventory holding cost. This includes the cost of providing space for the materials and insuring items. 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 inventory. The manager must decide on the order level and order quantity for each item within product subcategory, in order to maximize expected profits under uncertain demand while minimizing the instances of running out of inventory (i.e., a 'stock out'). There are also other criteria that can be applied which have not been thoroughly investigated.

Determining the appropriate stock level that will maximize profit under probabilistic consumer demand is known as stochastic optimization; this is different in nature to deterministic optimization, where data are provided in advance and are therefore known. In such stochastic situations it becomes difficult to formulate models accommodating so many factors. According to Kelton and Sadowski (2009), 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 of inventory 'expires' it would trigger an event and a change in the system state); this is a necessary precondition which makes this type of simulation more appropriate than continuous simulation for the modeling of substitutable and perishable inventory systems.

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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). Typically, a hierarchy of product group is used and within each of these groups are categories. Furthermore, categories can be defined into subcategories. Finally, many product variants are divided within each of these subcategories. 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 yoghurt or liquid drinks. Yoghurt can be divided by favors and then by sizes (e.g., plain, peach, or strawberry flavors and sizes such as 180mL or 110mL).

In real management settings, managers must decide what to set as 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 with the lowest cost. Some of these costs that play an important role in perishable inventory management include ordering cost, holding cost, disposal cost and shortage/backlog cost. Nahmias (1982) gave a comprehensive review for the perishable inventory theory. The perishable inventory problem is classified into two basic categories of management systems: periodic review (monitoring inventory levels at fixed intervals) and continuous review (monitoring inventory levels continually). From a practical perspective, periodic review has been widely used for a long period of time due to the relative simplicity in application. It simply involves knowing the amount of inventory at a particular point in time and reviewing the inventory on a regular basis thereafter. For example, a store-person may count the inventory once per week. This means the on-hand inventory is known at a specific time and can be used to calculate how much more inventory is required in the next order.

Many people will be familiar with a well-known, single period perishable inventory model: the Newsvendor model. This was named for the 'newsboy' that would need to buy a stack of newspapers before shifting them to another location for sale to customers. The entrepreneurial newsvendor had to calculate the likely number of newspapers required; if too many were purchased, they would be worthless at the end of the day, while if too few were purchased, they would lose potential sales (Nahmias, 2011).

To expand market share, many producers tend to provide more product lines, and many retailers opt to provide great choices for consumers by introducing new brands, more flavors or sizes of existing products, or new products with varied attributes. Consequently, this greater choice for consumers creates additional managerial challenges in terms of setting inventory management policies to maximize total profit. The managers must take into account the effects of substitution on inventory management system. There are two scenarios for product substitution called consumer-driven substitution and decision-maker driven substitution. In consumer-driven substitution, the customer's willingness to substitute during a stock out is a major factor. In contrast, decision-maker driven substitution involves a managerial decision to substitute a given product with a different variant of the product.

Perishability relates to the deterioration of a product over time and is often associated with fresh food; a cut of meat will quickly 'go bad' if it is exposed to warmth and sunlight, creating food safety issues for consumers. Globalization has created a big change in consumers' behavior as it has led to many people to seek superior quality foods, leading to an increase in the global trade in food products as some are produced in specialized locations. Developing countries are now frequently focusing on exporting products that they have distinct advantages in producing or where there is some measure of prestige associated with the product from their specific region. This behavior creates more jobs and more income for developing countries. Supply chain management has become increasingly important as the volumes of perishable products from developing countries (e.g., Vietnam and Mexico) have increased.

The suppliers are faced with the important issue to consider what to offer the customers when the customers want high service levels, lower costs, and an improved quality of product. Roberti (2005) asserted that around 10% of all perishable goods are wasted because of unacceptable levels of deterioration before the customer goes to buy it. Another example is the loss almost blood platelet units (used in blood transfusions) that expire without being transfused - these expired units impose a significant financial burden on health services. Therefore, the application of perishable inventory models is needed to provide higher customer service level and lower waste.