Aligning Aggregate Planning with (s,S) Inventory Model in a Stochastic Demand Environment

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ABSTRACT

Designing an aggregate plan is essential for firms to improve the efficiency of their inventory management as well as maintaining supplier relationships over a long run. Aggregate plan is primarily a function of demand uncertainty and the inventory policy in place. Firms tend to follow either a periodic review model (\((s, S)\) system) or a perpetual model (\((Q, R)\) system) for managing inventory time to time; the former being more prevalent due to lower inventory monitoring costs associated. The article proposes a mathematical model that incorporates the principles of \((s, S)\) inventory model in deciding on the key components of an aggregate plan for each period in a multi-period stochastic demand environment for both stationary and non-stationary demand scenarios. The article also provides numerical illustrations to demonstrate the application of the model.

KEYWORDS

Expected Order Quantity, Inventory, Mathematical Modeling, Non-Stationary Demand, Ordering Policy, Probability of Order Placement, Stationary Demand, Stock-Out

1. INTRODUCTION

Firms faced with stochastic demand situations often indulge in proper inventory management systems to reduce costs. An immaculate inventory system not only relates to everything a firm does to track procurement and review current stock levels but it also ensures that customers receive goods on time. In order to do so, the foremost objective is always to figure out exactly how much stock flows through the firm at a given point in time. Second, the success of an inventory management system is also dependent on how a firm identifies and works alongside with its suppliers in forecasting inventory requirements, processing purchase orders, managing delivery schedules and many more over a planning horizon which typically varies from 3 to 18 months. It is thereby a prevalent managerial practice to create an aggregate plan that is circulated across the suppliers. This plan is intended to satisfy the demand forecasts along periodic thresholds at a minimum cost throughout the supply chain of the firm. In recent years, both in practice and theory, there is a widespread recognition of how essential it is to view multi-echelon and multi-level production/distribution networks (where an item moves through more than one step before reaching the final customer) as a single holistic entity. Researchers believe that this paradigm shift has the potential to improve the profitability of the supply chain as a whole.

Managing inventory becomes seemingly difficult both at period level as well as at aggregate level when demand uncertainty exists in the supply chain. For shorter periods, inventory managers

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popularly resort to the use of periodic inventory system (popularly known as the \((s, S)\) system) or a perpetual inventory system (popularly known as the \((Q, R)\) system) to ascertain stock levels at the beginning of a period, stock bought and sold during a period and stock remaining at the end of a period in case of multi-period inventory models. The behavior of either of the systems depend on how often inventory is checked, thus giving rise to their periodic and perpetual nature respectively. However, the use of inventory models to determine aggregate plans in a stochastic demand environment is still rare. Indeed, managers devise aggregate plans to balance capacity and demand and minimize costs, however the demand considered in devising these plans does not follow any distribution pattern. This can be in part attributed to the difficulty in modeling aggregate plans by inclusion of inventory management systems due to the need of the consideration of additional complications such as probabilistic nature of the ordering processes or stochastic and non-stationary nature of demand. For instance, in the \((s, S)\) model, when the inventory level in-hand drops down to a minimum \(s\), the inventory management system generates a request for a replenishment order that restores the in-hand inventory to a target, or maximum, \(S\). Thus, in a multi-period \((s, S)\) model the focus is on identifying the optimum ordering policy for every period given the inventory level at the beginning of each. This implies that one of the key variables for successful implementation of a multi-period \((s, S)\) model is the level of inventory at the beginning of each period. In an aggregate plan, which is basically a series of such multi-periods over a long planning horizon, it is often difficult to ascertain or even predict the level of inventory at the beginning of the subsequent periods well in advance. The objective of the paper is thus, to derive an aggregate inventory estimate by integrating \((s, S)\) inventory model for uncertain demand conditions. Additionally, the proposed setup has been further demonstrated by presenting numerical illustrations.

2. LITERATURE REVIEW

Deterministic aggregate planning models are considered as one of the earliest applications of optimization models in industry. In an aggregate planning problem of a firm, the firm determines the optimal way to meet the forecasted demand in advance of 3 to 18 months to enable the managers to take informed decisions on the related matters. Though predominantly the aggregate planning problem is presented in the context of a manufacturer, the same idea can be applicable for other players in the supply chain. Modigliani & Hohn (1955) and Holt, Modigliani, & Muth (1956) first introduced the idea of such problem, and later various researchers studied the same with different approaches in different contexts. These models are generally built in the context of a finite time horizon divided into discrete time periods, and the output of the models are decision variables such as production and staffing levels for each period. Saad (1982) classified different conventional approaches to solve an aggregate planning problem in six categories, namely: (1) linear programming (LP) (Charnes, 1961), (2) linear decision rule (Holt et al., 1956), (3) transportation method (E. Bowman, 1956), (4) management coefficient approach (E. H. Bowman, 1963), (5) search decision rule (Taubert, 1968), and (6) simulation (Jones, 2012). In a then comprehensive study, Nam & Logendran (1992) prepared a review on different aggregate planning models from 140 journal articles and 14 books. Apart from the already mentioned classes, researchers have also used Multi Criteria Decision Making Methods (MCDMs) (Baykasoglu, 2001; Masud & Hwang, 1980), goal programming (Goodman, 1974), fuzzy optimization (Fung, Tang, & Wang, 2003; Lee, 1990) and Optimal Control (OC) formulation (Davizón, Martínez-Olvera, Soto, Hinojosa, & Espino-Román, 2015) for solving aggregate planning problems. Tajadod, Abedini, Rategari, & Mobin (2016) have done a comparative study of different MCDM approaches for aggregate planning of maintenance strategy selection. Researchers also have integrated aggregate planning problems with other decision-making processes like scheduling (Buxey, 1993), manpower planning (Mazzola, Neebe, & Rump, 1998), long set up time problems (Xue, Felix
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