Chapter 19
The Analysis of Zero Inventory Drift Variants Based on Simple and General Order-Up-To Policies

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ABSTRACT

In this paper, simple and general Order-Up-To (OUT) models with Minimum Mean Square Error (MMSE) forecast for the AR(1) demand pattern are introduced in the control engineering perspective. Important insights about lead-time misidentification are derived from the analysis of variance discrepancy. By applying the Final Value Theorem (FVI), a final value offset (i.e., inventory drift) is proved to exist and can be measured even though the actual lead-time is known. In this regard, to eliminate the inherent offset and keep the system variances acceptable, two kinds of zero inventory drift variants based on the general OUT model are presented. The analysis of variance amplification suggests lead-times should always be estimated conservatively in variant models. The stability conditions for zero inventory drift variants are evaluated in succession and some valuable attributes of the new variants are illustrated via spreadsheet simulation under the assumption that lead-time misidentification is inevitable.

INTRODUCTION

The use of control engineering approaches to solve production and inventory problems has been well studied. Simon (1952) initiated this research stream using Laplace-transform in continuous time scale. This approach was quickly translated into the newly favored z-transform because of the discrete nature of the practical problems. Many researchers, especially the professors from Linköping University and Cardiff University, tried to improve it thereafter. Coyle (1977) presented the Inventory and Order Based

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Production Control System (IOBPCS) model, which laid the foundation of a generic family of production control systems. Disney and Towill (2005) reviewed the IOBPCS family of decision support systems. To formalize the decision making process by utilizing simple and robust algorithms, Sterman (1989) suggested that a decision making model should allow suitable consideration of the pipeline to lead to stable dynamic behavior. This approach is known as Automatic Pipeline, Variable Inventory and Order Based Production Control System (APVIOBPCS), which was examined by John et al. (1994) via mathematical and simulation analysis. The equivalence of APVIOBPCS model and Oder-Up-To (OUT) policy was subsequently established by Dejonckheere et al. (2003), who also proposed general OUT rule to decrease the bullwhip effect and to generate smoothing orders.

All the policies mentioned before are under the assumption of having accurate estimates of the production and delivery lead-times. It's readily shown that systems would suffer from inventory drift if the lead-time is misidentified (John et al., 1994). Inventory drift is used to describe the phenomena that inventory levels do not lock on target levels over time when a step change in the consumption rate has occurred (Disney & Towill, 2005). It affects the net stock level and thus definitely changes system dynamic. The most effective solution is monitoring actual lead-times continuously. However, this requires significant amount of management effort, and that no theoretical support on the stability.

2. LITERATURE REVIEW

After searching papers concerning inventory drift, much fewer were found than we expected. Two seminal papers, written by John et al. (1994) and Disney and Towill (2005) respectively, both worked on APVIOBPCS model or OUT policy with independent and identically distributed (i.i.d.) demand and exponential smoothing forecasting. John et al. (1994) first examined the existence of inventory drift using the Final Value Theorem (FVT) when the lead-time estimation was not accurate. Then Disney and Towill (2005) presented a novel Estimated Pipeline Variable Inventory and Order Based Production Control System (EPVIOBPS) to eliminate the inventory drift instead of monitoring actual lead-times continuously. When facing different demand patterns or using different forecasting methods, sometimes the inventory deficit is inherent even though the accurate lead-time is known. Is the solution presented still effective? No clear answer has been found so far based on the literature. However, we prove the solution presented by Disney and Towill (2005) is not suitable for OUT policy with Minimum Mean Square Error (MMSE) forecast, which will be explained later in this article.

An outstanding order policy not just has zero inventory drift. As stated by Disney et al. (2006), inventory managers must balance two primary factors on making replenishments. One is the order variability measured by the bullwhip effect (i.e., the ratio of the variance of orders over the variance of demand). The other is the variance of the net stock measured by the net stock amplification (i.e., the ratio of net stock variance over the variance of demand). Trying to dampen the bullwhip effect may have a negative impact on net stock amplification and vice versa (Disney et al., 2006).

So the task of this paper is to analyze and design better replenishment policies, which concern factors in every respect. On one hand, new order policy should not arouse inventory drift and still keep the system stable. On the other hand, both variance amplifications from new order policy should be kept in an acceptable range, although it may never be totally avoided. In the ensuing paragraphs, we analyze the widely used OUT policy and point out its shortcomings. Then we present the new zero inventory drift model and report the simulation results compared to simple OUT policy. Finally, the paper concludes with a summary and a look ahead to future research.