



Common inventory modeling assumptions that fall short: Arborescent networks, Poisson demand, and single-echelon approximations

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ABSTRACT

Traditional multi-echelon inventory theory focuses on arborescent supply chains that use a central warehouse which replenishes remote warehouses. The remote warehouses serve customers in their respective regions. Common assumptions in the academic literature include use of the Poisson demand process and instantaneous unit-by-unit replenishment. In the practitioner literature, single-echelon approximations are advised for setting safety stock to deal with lead time, demand, and supply variations in these settings. Using data from a U.S. supplier of home improvement products, we find that neither the assumptions from the academic literature nor the approximations from the practitioner literature necessarily work well in practice.

In a variation of the strictly arborescent supply chain, the central warehouse at our real company not only replenishes other warehouses but also meets demand from customers in the region near the central warehouse. In this paper, we study this dual-role central warehouse structure, which we believe is common in practice. Using high and low volume product demand data from this company, we use Monte Carlo simulations to study the impact of (1) the use of a dual-role centralized warehouse, (2) common demand assumptions made in multi-echelon research, and (3) single-echelon approximations for managing a multi-echelon supply chain. We explore each of these under both centralized and decentralized control logic. We find that the common assumptions of theoretical models impede their usefulness and that heuristics that ignore the actual supply chain structure fail to account for additional opportunities to utilize safety stock more effectively. Researchers should be aware of the gap between standard assumptions in traditional literature and actual practice, and critically evaluate their assumptions to find a reasonable balance between tractability and relevance.

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1. Introduction

The motivation for this article derives from work with a U.S. supplier of home improvement products. BIGCO, as we call it, had been struggling with the management of inventory in its multi-echelon supply chain which serves customers in North America. The firm invested in a state-of-the-art inventory control system that offered nearly real-time inventory information and statistical inventory control logic, but the algorithms were based on traditional assumptions and heuristics that were inconsistent with the actual structure and nature of the company's supply chain. The result was that the firm required large stores of inventory in order to maintain desired service levels.

We seek insights into why the theoretical calculations in traditional inventory literature are practically useless in an actual multi-echelon inventory system and how future research might

be made more relevant. We introduce an alternate supply chain structure—the dual-role central warehouse—common in industry but ignored in literature. In doing so, we address a problem relevant to academics and practitioners alike. We review existing inventory literature to understand the analytical models available to BIGCO and then develop a simulation with structure and parameter values to reflect its managerial situation. Using historical demand data from this company, we assess BIGCO's current approach compared with exact and heuristic models as suggested by prior literature. We also compare these methods with an optimal policy that we find through simulation.

Managing multi-echelon inventory has been a popular topic since a seminal article by Clark and Scarf (1960). A significant part of the literature can be characterized as highly theoretical with a focus on determining the structure of optimal policies or establishing a control logic that balances the flow of inventory between a central warehouse and a set of remote sites that serve regional customers. Although most theoretical inventory literature remains too abstract to be of use in a real-world setting, an interesting and definitive article published by Gallego et al. (2007) prescribes a

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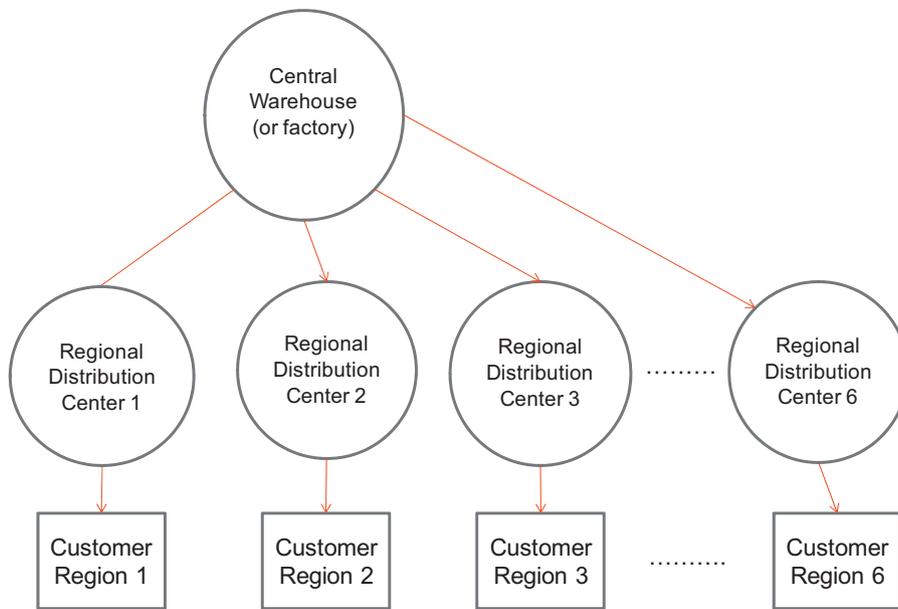


Fig. 1. A traditional arborescent supply chain.

concrete logic for managing inventory in the common setting of a warehouse that serves a set of satellite warehouses, which in turn support regional customers. This setting is commonly referred to as an arborescent network design. These authors develop scenarios of both local and centralized control and find “fast, transparent, effective, and robust heuristics and approximations” (Gallego et al., 2007, p. 503) for managing these systems. Their article contrasts with most research, in that it provides managers with actual guidance for how to use arborescent inventory systems to determine optimal policies. However, for tractability the authors make some significant assumptions related to the network structure, demand distribution, lot size, lead time, and control logic, comparable to those made by others doing similar research. In our research, we test the applicability of this practical work to a real-world setting with (some significant) differences in the assumptions.

Our objective is to evaluate how assumptions significantly influence the relevance of research to real-world applications.

Specifically, the key assumptions and policies we test are (1) the supply chain structure, (2) the demand distribution, and (3) the use of a single-echelon approximation to manage a multi-echelon supply chain. The first two of these assumptions are common in the academic literature while the third is common among practitioners. We explore the performance implications of each under both centralized versus decentralized control. In our literature review, we show how these assumptions are used in seminal articles published in the past 50 years. We argue that researchers should be aware of the gap between standard assumptions in traditional inventory literature and actual practice, and evaluate critically their assumptions to find a reasonable balance between tractability and relevance.

Our research contributes to actual practices of operations and supply chains by (1) providing a detailed description of the practices in a particular firm that has a common supply structure not addressed in the literature, (2) identifying the lack of theory to

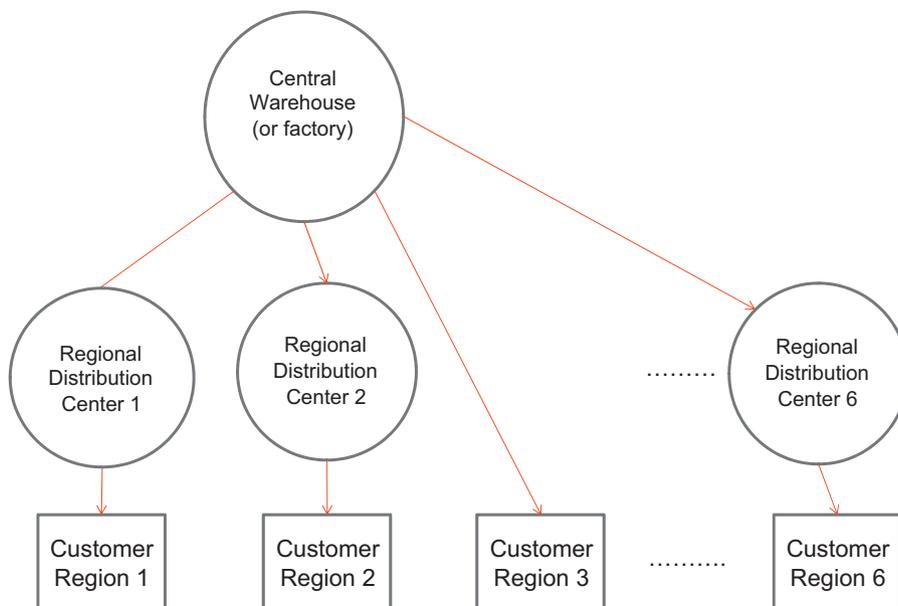


Fig. 2. A supply chain with a dual-role central warehouse.

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