Inventory Management: Modeling Real-life Supply Chains and Empirical Validity

Other titles in Foundations and Trends® in Technology, Information and Operations Management

Matching Supply and Demand for Hospital Services
Diwakar Gupta and Sandra J. Potthoff
ISBN: 978-1-68083-108-5

Quantity Discounts: An Overview and Practical Guide for Buyers and Sellers
Charles L. Munson and Jonathan Jackson
ISBN: 978-1-60198-888-1

Management Systems Standards: Diffusion, Impact and Governance of ISO 9000, ISO 14000, and Other Management Standards
Pavel Castka and Charles J. Corbett
ISBN: 978-1-60198-884-3

Designing and Controlling the Outsourced Supply Chain
Andy A. Tsay
ISBN: 978-1-60198-844-7

Inventory Management: Modeling Real-life Supply Chains and Empirical Validity

Ton de Kok
School of Industrial Engineering
Eindhoven University of Technology,
The Netherlands
a.g.d.kok@tue.nl

now
the essence of knowledge
Boston — Delft

Full text available at: http://dx.doi.org/10.1561/0200000057

Foundations and Trends® in Technology, Information and Operations Management

Published, sold and distributed by:
now Publishers Inc.
PO Box 1024
Hanover, MA 02339
United States
Tel. +1-781-985-4510
www.nowpublishers.com
sales@nowpublishers.com

Outside North America:
now Publishers Inc.
PO Box 179
2600 AD Delft
The Netherlands
Tel. +31-6-51115274

The preferred citation for this publication is

T. de Kok. *Inventory Management: Modeling Real-life Supply Chains and Empirical Validity*. Foundations and Trends® in Technology, Information and Operations Management, vol. 11, no. 4, pp. 343–437, 2018.

ISBN: 978-1-68083-417-8
© 2018 T. de Kok

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, mechanical, photocopying, recording or otherwise, without prior written permission of the publishers.

Photocopying. In the USA: This journal is registered at the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923. Authorization to photocopy items for internal or personal use, or the internal or personal use of specific clients, is granted by now Publishers Inc for users registered with the Copyright Clearance Center (CCC). The 'services' for users can be found on the internet at: www.copyright.com

For those organizations that have been granted a photocopy license, a separate system of payment has been arranged. Authorization does not extend to other kinds of copying, such as that for general distribution, for advertising or promotional purposes, for creating new collective works, or for resale. In the rest of the world: Permission to photocopy must be obtained from the copyright owner. Please apply to now Publishers Inc., PO Box 1024, Hanover, MA 02339, USA; Tel. +1 781 871 0245; www.nowpublishers.com; sales@nowpublishers.com

now Publishers Inc. has an exclusive license to publish this material worldwide. Permission to use this content must be obtained from the copyright license holder. Please apply to now Publishers, PO Box 179, 2600 AD Delft, The Netherlands, www.nowpublishers.com; e-mail: sales@nowpublishers.com

Full text available at: http://dx.doi.org/10.1561/0200000057

Foundations and Trends® in Technology, Information and Operations Management
Volume 11, Issue 4, 2018

Editorial Scope

Topics

Foundations and Trends® in Technology, Information and Operations Management publishes survey and tutorial articles in the following topics:

- B2B Commerce
- Business Process Engineering and Design
- Business Process Outsourcing
- Capacity Planning
- Competitive Operations
- Contracting in Supply Chains
- E-Commerce and E-Business Models
- Electronic markets, auctions and exchanges
- Enterprise Management Systems
- Facility Location
- Information Chain Structure and Competition
- International Operations
- Marketing/Manufacturing Interfaces
- Multi-location inventory theory
- New Product & Service Design
- Queuing Networks
- Reverse Logistics
- Service Logistics and Product Support
- Supply Chain Management
- Technology Management and Strategy
- Technology, Information and Operations in:
  - Automotive Industries
  - Electronics manufacturing
  - Financial Services
  - Health Care
  - Media and Entertainment
  - Process Industries
  - Retailing
  - Telecommunications

Information for Librarians

Foundations and Trends® in Technology, Information and Operations Management, 2018, Volume 11, 4 issues. ISSN paper version 1571-9545. ISSN online version 1571-9553. Also available as a combined paper and online subscription.

Contents

Inventory Management: Modeling Real-life Supply Chains and Empirical Validity

Ton de Kok

School of Industrial Engineering, Eindhoven University of Technology, The Netherlands; a.g.d.kok@tue.nl

---

ABSTRACT

It is our intention to write a different overview of inventory models, from single item single echelon models to multi-item multi-echelon models, then is mostly provided in text books on Operations Management. We hope that this monograph provides complementary knowledge. Instead of starting with inventory models that are tractable from a mathematical point of view, we start from the inventory management problem and the modeling challenges to be faced. We present the economic order quantity problem from the perspective of Return On Investment instead of from a cost perspective. We show that the Newsvendor fractile emerges from virtually any model with linear holding and penalty costs. And we discuss the complexities of multi-item multi-echelon inventory systems by developing necessary and sufficient conditions operational control policies for such systems should satisfy.

Ton de Kok (2018), "Inventory Management: Modeling Real-life Supply Chains and Empirical Validity", Foundations and Trends® in Technology, Information and Operations Management: Vol. 11, No. 4, pp 343–437. DOI: 10.1561/0200000057.

1

Introduction

Inventory management has been a core topic of Operations Research since the 1950s. Inventory can be seen as a means to create efficiency in production and distribution: it enables scale by allowing to accumulate demand until a batch quantity is released that can be produced and shipped efficiently. This role of inventory is of great importance in process industries, where set-up times are considerable. Inventory can be seen as a means to ensure sufficient customer service: as demand is unpredictable we must hold inventory in case there are unexpected surges in demand. This role of inventory is of great importance in retail, as we expect a product to be available off-the-shelf or at our doorstep within 24 hours.

Inventory can also be seen as a symptom of bad management, as waste of capital. Reduction of inventory capital has been high on the priority lists of CEOs over the last four decades. In the early 1980s, the Just In Time (JIT) philosophy proclaimed zero inventory as the key objective to ensure continuous improvement of processes, leading to less process variability, shorter processing time, smaller production and transportation batches, and higher product yield. In many businesses inventory is an unfavorable term. Euphemisms for inventory were introduced, such as buffers and supermarkets. Despite the continuous efforts to reduce process durations and volatility, zero inventory will remain a mirage as fundamental uncertainty in demand and supply cannot be eliminated and trading-off efficiency, quality, customer service and cost of inventory capital inevitably yield the need for inventory at various places in global and local supply chains, acting as the lubricant.

The trade-offs to be made have been studied extensively in the inventory management literature. This has led to optimal inventory control policies for various supply chain structures with various cost assumptions. Clearly, most results are known for the simplest inventory management situation, i.e., a single product at a single location. But both the qualitative and quantitative understanding of this simple inventory management situation is a building block for understanding inventory management in practice, where we have to deal with multiple items in multiple locations.

Thus, inventory control policies are implemented in every ERP (Enterprise Resource Planning) system, such as SAP and Oracle, and used in almost every company. ERP systems are the transaction backbone systems of enterprises in which product and process data are stored and each customer order, production order, and purchase order is tracked and traced. Over the course of a few decades, ERP systems have been enriched with planning and control modules that support inventory management, production management, and sales. Despite the availability and use of inventory control policies in ERP systems, we observe that most of the control-policy-based replenishment proposals are overwritten by manual decisions. Indeed, being an inventory manager or planner, you want to manage and plan, and you can do better than the inventory management system. Unfortunately, it is shown again and again that proper use of inventory management systems yields higher service and lower costs at the same time. We observe that inventory managers have difficulties with the interpretation of unexpected events regarding demand and supply, i.e., distinguishing noise from signal. At the same time we observe that inventory managers have access to relevant information that an ERP system's inventory control module cannot exploit. This calls for the design of an inventory management approach that combines the strength of mathematically rigorously determined inventory control policies and tacit knowledge of human decision makers. This monograph is motivated by these observations and builds on 32 years of working in (8 years) and in cooperation with (the next 24 years) industry, applying and implementing inventory control models.

It is our intention to write a different overview of inventory models, from single-item single-echelon (SISE) models to multi-item multi-echelon models (MIME), than what is mostly provided in text books on Operations Management (e.g. Nahmias and Olsen (2015) and Silver *et al.* (2016)). We hope that this monograph provides complementary knowledge. Instead of starting with inventory models that are tractable from a mathematical point of view, we start from the inventory management problem and the modeling challenges to be faced.

The first section of this monograph is devoted to modeling inventory systems so that these models are empirically valid by proper calibration. Inventory models are abstractions that cannot capture all possible actions to balance supply and demand but with proper measurement of inventory management performance, we can set the parameters in such a way that the customer service is consistently at the right level. We hypothesize that it is better to use mathematically tractable models and appropriately chosen performance measures than to identify all possible actions under specific circumstances and model these explicitly. We found that many specific actions are focussed on preventing stockouts. Typically, such actions either postpone customer demand or expedite production orders released earlier. Herewith we create correlation between occurrences of high demands and arrivals of production orders that satisfy them. Ignoring this correlation yields considerable underestimates of customer service, while modeling this correlation is mostly mathematically intractable. Thus we propose to measure performance *before specific actions are taken*, which yields the notion of Intervention Independent Performance (IIP) indicators. A company must also measure the effectiveness of the specific actions taken, which yields the notion of Intervention Dependent Performance (IDP) actions. Applying IIP indicators in combination with inventory models in research projects provided an empirical basis for the validity of this approach: in both single-item single-echelon (SISE) situations and multi-item multi-echelon (MIME) inventory systems we could explain the *quantitative* relationship between capital invested in item inventories and end-item customer service. One should not underestimate the importance of this finding: it provides a scientific basis for the use of inventory models as studied in OR literature. Here we take the position that mathematical models and their analysis are not science without empirical data supporting the causalities embodied by the model.

The second section discusses SISE models. We show that under linear holding and penalty costs, the Newsvendor equation holds for virtually any sensible control policy. The Newsvendor equation states that the non-stockout probability at an arbitrary point in time equals the quotient of penalty cost rate and the sum of holding cost rate and penalty cost rate. We show that inventory management performance is primarily determined by average inventory and order frequency. In our view, in inventory management education, there should be more emphasis on average inventory levels instead of safety stocks. After all, we pay for the capital tied up in average inventories, not in safety stocks. As capital is tied up in inventory, it is relevant to consider trade-offs from a Return On Investment (ROI) point of view. We discuss the impact of the change from cost minimization to ROI maximization using the Economic Order Quantity model. We discuss the prerequisites for empirical validity of the basic inventory models. One lesson should stand out here: mathematical analysis must be rigorous. Otherwise it is likely that the resulting control policies do not make any sense to inventory planners, and they are right in that case.

The third section extensively discusses MIME inventory systems. This discussion is not aiming at a complete overview of the state-of-the-art on multi-echelon inventory system research. Having worked on the subject for over 25 years, we conclude that the emphasis in the scientific literature has primarily been on optimal policies under specific assumptions on the structure of multi-item multi-echelon systems, such as serial, divergent, or convergent, (cf. Axsäter (2003) and Song and Zipkin (2003)), and much less on the underlying complexity of general MIME systems. There are no serial systems in practice. At best they are divergent (i.e., each item has a single upstream predecessor, or child) in the form of retail and spare parts distribution networks. Convergent MIME systems, i.e., systems in which each item has at most one parent, are rare, as most companies sell more than one product. In literature, convergent MIME systems are also referred to as (pure) assembly systems. So most of the time supply chains are networks with both embedded divergence and convergence (i.e., an item may have multiple children upstream and multiple parents downstream). Under uncertainty you are continually confronted with the dilemma to allocate item availability among parent items, i.e., the items that use the item under consideration. Allocating less to a particular parent item implies that less is needed of other child items used by this parent item, whereby these child items can be used for other parent items, but then we need other items as well. We assume that orders released to the shopfloor can be executed with 100% due date reliability, provided that material (and resource) constraints are taken into account. This implies that we model general MIME systems with constant flow times, i.e., constant times between order release and order receipt in inventory. In order to create a benchmark for control policies for general MIME systems, we formulate necessary conditions for a control policy to yield feasible solutions. Herewith we bridge the gap between mathematical programming formulations of supply chain planning problems that concern the problem to be solved today, and the stochastic dynamic programming formulations that focus on control policy structures that generate optimal policies, and resulting solutions, over a relevant period of time.

The most frequently used planning logic to plan and manage MIME inventory systems in practice is called Material Requirements Planning (MRP I). The main principles of MRP I logic are lead-time offsetting and dependent demand. Starting from the constraint to maintain a safety stock at the end of each future period, and knowing future (gross) requirements for an item, as well as outstanding orders, inventory balance equations are used to determine the replenishment quantities in future periods. By offsetting the replenishment quantities by the item lead time we obtain planned order quantities. These planned order quantities are translated to so-called dependent demand for child items by multiplying the order quantities by the number of child items needed to make one item. Through proper administration we can determine the dependent demand for each item and derive the planned order for each item. For further details on the logic we refer to subsection 4.4. Initially

Material Requirements Planning was abbreviated as MRP, but in the 1980s the MRP logic was embedded in an overall framework for planning and control called Manufacturing Resource Planning, which, having the same three-letter-abbreviation, was denoted as MRP II (cf. Vollmann *et al.* (2005)). MRP I was introduced as a "killer app" for IBM mainframes in the early 1960s, and promoted by the American Production and Inventory Control Society (APICS) from 1970 onwards. For a historic perspective on MRP I, we refer to Wilson (2016). We find that MRP I logic does not pass the test of adhering to material availability constraints. This finding cannot be emphasized often enough, as it explains symptoms like nervousness and expediting. On my return to academia in the early 1990s, I set myself the research objective to determine safety stocks in MRP I. Pursuing this objective, I found that my quest would be in vain, because the MRP I logic is not mathematically sound. MRP I logic turned out to be a logic that generates requirements, but it is not a logic for planning. Planning involves the balancing of demand and supply, knowing that you must take decisions on supply before demand is known. That is why in general MIME systems there is a continual misalignment between demand and supply that is resolved by keeping inventory. However, inventory does not always resolve the misalignment, and that is where scarce child item material availability must be allocated among multiple parent items with the consequences sketched above: a problem mess, a Gordian knot. The concept of Synchronized Base Stock (SBS) policies for operational control of general MIME inventory systems is cutting this Gordian knot at the expense of suboptimality (though SBS policies are optimal for divergent systems and convergent systems). The SBS concept generates a deep insight into the natural decision hierarchy embedded in any general multi-item multi-echelon system. In-depth case studies in the context of MSc thesis projects at companies indicate that the assumption of SBS policies yields empirically valid results, even though none of these companies used SBS policies. The only explanation for this result is that also in MIME inventory systems inventory performance is driven by average inventories and order frequencies.

The fourth section briefly discusses the additional issues that come with taking into account resource constraints. While for single-echelon systems finite capacity is (relatively) easy to deal with, this is not the case for multi-echelon systems. I consider the results for serial systems in Janakiraman and Muckstadt (2009) as a milestone in the analysis of capacitated MIME systems, and at the same time as a clear indication of the challenges ahead of us when trying to tackle this problem for general structures.

Inventory management is a challenging research subject due to its structural complexity, represented by general networks of interacting stockpoints, and the complexity induced by demand and supply uncertainty. The curses of dimensionality prohibit the calculation of optimal policies. I hope that this fact is a reason to pursue more research with great practical relevance. Admittedly, when allowing yourself to write down that something on the left hand side of an "equation" is approximately equal to something on the right hand side, you may be overwhelmed by the possible alternative routes that can be taken towards policies and algorithms. Yet at the end of the day, applied science should be about reality and reality happens to be complex.

References

Axsäter, S. 2015. *Inventory Control. International Series in Operations Research & Management Science.* Springer International Publishing. URL: https://books.google.nl/books?id=v9YjCgAAQBAJ.

Axsäter, S. 2003. "Supply chain operations: Serial and distribution inventory systems". *Handbooks in operations research and management science.* 11: 525–559.

Bisschop, J. 2007. "Supply chain performance evaluation : application of the synchronised base stock policy in a high-tech complex equipment supply chain with contract manufacturers". *MA thesis.* School of Industrial Engineering, Eindhoven University of Technology. URL: https://pure.tue.nl/ws/files/47041546/631639-1.pdf.

Camp, B. 2002. "Startrek supply chain planning : modeling, optimization and generalization". *MA thesis.* School of Industrial Engineering, Eindhoven University of Technology. URL: https://pure.tue.nl/ws/files/46793392/561053-1.pdf.

Clark, A. J. and H. Scarf. 1960. "Optimal policies for a multi-echelon inventory problem". *Management Science.* 6(4): 475–490.

Daganzo, C. F. 2005. *Logistics Systems Analysis.* Springer.

de Kok, A. 1991a. "Basics of Inventory Management". *Tech. rep.* No. 510, 521-525. Tilburg University.

de Kok, A. 1991b. "Basics of inventory management (Part 5): The (R,b,Q)-model". *Tech. rep.* 1991.

de Kok, A. 1993. "Demand management in a multi-stage distribution chain". *Tech. rep.* No. 93-35. Eindhoven University of Technology.

de Kok, A. 1998. "Inventory control with manufacturing lead time flexibility". *Tech. rep.* No. 345. Eindhoven University of Technology. 20.

de Kok, A. 2001. "Comparison of Supply Chain Planning concepts for general multi-item, multi-echelon systems". *Tech. rep.* Research Report TUE/TM/LBS/01-03. Eindhoven: Technische Universiteit Eindhoven. URL: https://pure.tue.nl/ws/files/3577889/552034.pdf.

de Kok, A. 2010. "Operations Management: Dancing the tightrope between physics and economics". In: *MSOM Conference, Haifa, Israel, June 27-29*.

de Kok, T. 2015. "Buffering against uncertainty in high-tech supply chains". In: *Proceedings of the 2015 Winter Simulation Conference*. IEEE Press. 2991–3000.

de Kok, T. G. 2003. "Ruin probabilities with compounding assets for discrete time finite horizon problems, independent period claim sizes and general premium structure". *Insurance: Mathematics and Economics*. 33(3): 645–658.

de Kok, T. G. 2017. "Modeling short-term manufacturing flexibility by human intervention and its impact on performance". *International Journal of Production Research*. 56(1-2): 447–458. DOI: https://doi.org/10.1080/00207543.2017.1401750.

de Kok, T. G. and J. C. Fransoo. 2003. "Planning Supply Chain Operations: Definition and Comparison of Planning Concepts". In: *Supply Chain Management: Design, Coordination and Operation*. Vol. 11. *Handbooks in Operations Research and Management Science*. Elsevier. 597–675. DOI: https://doi.org/10.1016/S0927-0507(03)11012-2.

de Kok, T. G. and J. W. Visschers. 1999. "Analysis of assembly systems with service level constraints". *International Journal of Production Economics*. 59(1): 313–326.

de Kok, T., F. Janssen, J. Van Doremalen, E. Van Wachem, M. Clerkx, and W. Peeters. 2005. "Philips electronics synchronizes its supply chain to end the bullwhip effect". *Interfaces*. 35(1): 37–48.

Dekker, R., M. Kleijn, and A. de Kok. 1998. "The break quantity rule's effect on inventory costs in a 1-warehouse, N-retailers distribution system". *Tech. rep.* No. 7. 61–68.

Diks, E. and A. de Kok. 1999. "Computational results for the control of a divergent N-echelon inventory system". *International Journal of Production Economics*. 59(1): 327–336.

Diks, E. B. and A. de Kok. 1998. "Optimal control of a divergent multi-echelon inventory system". *European Journal of Operational Research*. 111(1): 75–97.

Doğru, M. K., A. de Kok, and G. Van Houtum. 2009. "A numerical study on the effect of the balance assumption in one-warehouse multi-retailer inventory systems". *Flexible Services and Manufacturing Journal*. 21(3-4): 114–147.

Edgeworth, F. 1888. "The mathematical theory of banking". *Journal of the Royal Statistical Society*. 51: 113–127.

Eppen, G. and L. Schrage. 1981. "Centralized ordering policies in a multi-warehouse system with lead times and random demand". *Multi-level production/inventory control systems: Theory and practice*. 16: 51–67.

Ettl, M., G. E. Feigin, G. Y. Lin, and D. D. Yao. 2000. "A supply network model with base-stock control and service requirements". *Operations Research*. 48(2): 216–232.

Federgruen, A. and P. Zipkin. 1984. "Computational issues in an infinite-horizon, multiechelon inventory model". *Operations Research*. 32(4): 818–836.

Federgruen, A. and P. Zipkin. 1986a. "An inventory model with limited production capacity and uncertain demands I. The average-cost criterion". *Mathematics of Operations Research*. 11(2): 193–207.

Federgruen, A. and P. Zipkin. 1986b. "An inventory model with limited production capacity and uncertain demands II. The discounted-cost criterion". *Mathematics of Operations Research*. 11(2): 208–215.

Fogarty, D. and T. Hoffmann. 1983. *Production and Inventory management*. Cincinnati, Ohio: South-Western Publishing Co.

Glasserman, P. and S. Tayur. 1994. "The stability of a capacitated, multi-echelon production-inventory system under a base-stock policy". *Operations Research*. 42(5): 913–925.

Glasserman, P. and S. Tayur. 1996. “A simple approximation for a multistage capacitated production-inventory system”. *Naval Research Logistics*. 43(1): 41–58.

Graves, S. C. and S. P. Willems. 2000. “Optimizing strategic safety stock placement in supply chains”. *Manufacturing & Service Operations Management*. 2(1): 68–83.

Graves, S. C. and S. P. Willems. 2003. “Supply chain design: safety stock placement and supply chain configuration”. *Handbooks in operations research and management science*. 11: 95–132.

Harris, F. 1913. “How many parts to make at once”. *Factory, The Magazine of Management*. 10(2): 135–136.

Hernandez Wesche, E. 2012. “Impacts op implementing a retailer cross-dock on the Western Europe Procter & Gamble supply chain”. *MA thesis*. School of Industrial Engineering, Eindhoven University of Technology. URL: https://pure.tue.nl/ws/files/46910223/739767-1.pdf.

Hopp, W. J. and M. L. Spearman. 2011. *Factory physics*. Waveland Press.

Huh, W. T. and G. Janakiraman. 2010. “Base-stock policies in capacitated assembly systems: Convexity properties”. *Naval Research Logistics (NRL)*. 57(2): 109–118.

Huh, W. T., G. Janakiraman, and M. Nagarajan. 2010. “Capacitated serial inventory systems: sample path and stability properties under base-stock policies”. *Operations Research*. 58(4-part-1): 1017–1022.

Huh, W. T., G. Janakiraman, and M. Nagarajan. 2016. “Capacitated multiechelon inventory systems: Policies and bounds”. *Manufacturing & Service Operations Management*. 18(4): 570–584.

Janakiraman, G. and J. A. Muckstadt. 2009. “A decomposition approach for a class of capacitated serial systems”. *Operations Research*. 57(6): 1384–1393.

Janssen, F. 2004. “Voorraadverlaging door SCM bij Diosynth”. *MA thesis*. School of Industrial Engineering, Eindhoven University of Technology. URL: https://pure.tue.nl/ws/files/46832256/577518-1.pdf.

Karaarslan, A., G. Kiesmüller, and A. de Kok. 2013. "Analysis of an assemble-to-order system with different review periods". *International Journal of Production Economics*. 143(2): 335–341.

Kiesmüller, G. P., T. G. de Kok, S. R. Smits, and P. J. van Laarhoven. 2004. "Evaluation of divergent N-echelon (s, nQ)-policies under compound renewal demand". *OR Spectrum*. 26(4): 547–577.

Kilger, C., H. Meyr, and H. Stadtler. 2015. "Supply chain management and advanced planning: concepts, models, software, and case studies".

Kleinrock, L. 1965. "A conservation law for a wide class of queueing disciplines". *Naval Research Logistics Quarterly*. 12(2): 181–192.

Køhler-Gudum, C. and A. de Kok. 2002. "A safety stock adjustment procedure to enable target service levels in simulation of generic inventory systems". *Tech. rep.* URL: https://pure.tue.nl/ws/files/3596094/554365.pdf.

Magnanti, T. L., Z.-J. M. Shen, J. Shu, D. Simchi-Levi, and C.-P. Teo. 2006. "Inventory placement in acyclic supply chain networks". *Operations Research Letters*. 34(2): 228–238.

Nahmias, S. and T. L. Olsen. 2015. *Production and operations analysis*. Waveland Press.

Orlicky, J. 1975. *Material requirements planning*. Mcgraw-Hill Education.

Parker, R. P. and R. Kapuscinski. 2004. "Optimal policies for a capacitated two-echelon inventory system". *Operations Research*. 52(5): 739–755.

Radstok, K. 2013. "Fast & slow freight distribution in the fast moving consumer goods industry". *MA thesis*. School of Industrial Engineering, Eindhoven University of Technology. URL: https://pure.tue.nl/ws/files/46922783/754756-1.pdf.

Roose, S. 2007. "Rethinking inbound operations management at Procter & Gamble Mechelen : multi-echelon inventory management applied in process industry". *MA thesis*. School of Industrial Engineering, Eindhoven University of Technology. URL: https://pure.tue.nl/ws/files/47021144/627272-1.pdf.

Rosling, K. 1989. "Optimal inventory policies for assembly systems under random demands". *Operations Research*. 37(4): 565–579.

Silver, E., D. Pyke, and R. Peterson. 1998. *Inventory Management and Production Planning and Scheduling*. New York: Wiley.

Silver, E. A., D. F. Pyke, and D. J. Thomas. 2016. *Inventory and Production Management in Supply Chains*. CRC Press.

Song, J.-S. and P. Zipkin. 2003. "Supply chain operations: Assemble-to-order systems". *Handbooks in operations research and management science*. 11: 561–596.

Spitter, J. M. 2005. *Rolling schedule approaches for supply chain operations planning*. Technische Universiteit Eindhoven Eindhoven. URL: https://pure.tue.nl/ws/files/2089632/200511140.pdf.

Trietsch, D. 1995. "Revisiting ROQ: EOQ for Company-Wide ROI Maximization". *The Journal of the Operational Research Society*. 46: 507–515.

Uquillas Andrade, R. 2010. "An integral supply chain operations planning system for a global pharmaceutical company". *MA thesis*. School of Industrial Engineering, Eindhoven University of Technology. URL: https://pure.tue.nl/ws/files/46966985/668984-1.pdf.

Van Cruchten, A. 2016. "Multi-echelon safety stock optimization under supply, process and demand uncertainties as a part of operational risk management". *MA thesis*. School of Industrial Engineering, Eindhoven University of Technology. URL: https://pure.tue.nl/ws/files/46933553/845023-1.pdf.

Van der Heijden, M. 1997. "Supply rationing in multi-echelon divergent systems". *European Journal of Operational Research*. 101(3): 532–549.

Van der Heijden, M., E. Diks, and A. de Kok. 1997. "Stock allocation in general multi-echelon distribution systems with (R, S) order-up-to-policies". *International Journal of Production Economics*. 49(2): 157–174.

van Houtum, G.-J., A. Scheller-Wolf, and J. Yi. 2007. "Optimal control of serial inventory systems with fixed replenishment intervals". *Operations Research*. 55(4): 674–687.

Van Pelt, T. 2015. "Multi-echelon inventory management at Sligro Food Group N.V." *MA thesis*. School of Industrial Engineering, Eindhoven University of Technology. URL: https://pure.tue.nl/ws/files/47009988/789280-1.pdf.

Van Wanrooij, M. 2012. "Strategic supply chain planning in a multi-echelon environment : identification of the CODP location constrained by controllability and service requirements". *MA thesis.* School of Industrial Engineering, Eindhoven University of Technology. URL: https://pure.tue.nl/ws/files/46910380/739787-1.pdf.

Vollmann, T., W. Berry, D. Whybark, and F. Jacobs. 2005. *Manufacturing Planning and Control for Supply Chain Management.* McGraw-Hill/Irwin.

Whitin, T. M. 1953. *The Theory of Inventory Management.* Princeton.

Whybark, D. C. and S. Yang. 1996. "Positioning inventory in distribution systems". *International Journal of Production Economics.* 45(1-3): 271–278.

Willems, S. P. 2008. "Data set—Real-world multiechelon supply chains used for inventory optimization". *Manufacturing & Service Operations Management.* 10(1): 19–23.

Wilson, J. M. 2016. "The origin of material requirements planning in Frederick W. Taylor's planning office". *International Journal of Production Research.* 54(5): 1535–1553.

Zipkin, P. 2000. *Foundations of Inventory Management.* Boston: McGraw-Hill.