

---

**On Replenishment Rules,  
Forecasting, and  
the Bullwhip Effect  
in Supply Chains**

---

# On Replenishment Rules, Forecasting, and the Bullwhip Effect in Supply Chains

---

**Stephen M. Disney**

*Cardiff University  
Aberconway Building, Colum Drive  
Cardiff, CF10 3EU, UK  
DisneySM@cardiff.ac.uk*

**Marc R. Lambrecht**

*Katholieke Universiteit Leuven  
Naamsestraat 69  
3000 Leuven, Belgium  
marc.lambrecht@econ.kuleuven.be*

**now**

the essence of **knowledge**

Boston – Delft

## **Foundations and Trends<sup>®</sup> in Technology, Information and Operations Management**

*Published, sold and distributed by:*

now Publishers Inc.  
PO Box 1024  
Hanover, MA 02339  
USA  
Tel. +1-781-985-4510  
[www.nowpublishers.com](http://www.nowpublishers.com)  
[sales@nowpublishers.com](mailto: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 S. M. Disney and M. R. Lambrecht, On Replenishment Rules, Forecasting, and the Bullwhip Effect in Supply Chains, *Foundations and Trends<sup>®</sup> in Technology, Information and Operations Management*, vol 2, no 1, pp 1–80, 2007

ISBN: 978-1-60198-132-5

© 2008 S. M. Disney and M. R. Lambrecht

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](http://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](http://www.nowpublishers.com); [sales@nowpublishers.com](mailto: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](http://www.nowpublishers.com); e-mail: [sales@nowpublishers.com](mailto:sales@nowpublishers.com)

**Foundations and Trends<sup>®</sup> in  
Technology, Information and Operations  
Management**  
Volume 2 Issue 1, 2007  
**Editorial Board**

**Editor-in-Chief:**

**Uday Karmarkar**

*Times Mirror Chair in Mgmt Startegy & Policy*

*The Anderson School at UCLA*

*Los Angeles, California 90095-1418*

*USA*

*uday.karmarkar@anderson.ucla.edu*

**Editors**

Uday Apte (Southern Methodist  
University)

Rajiv Banker (Temple University)

Gabriel Bitran (MIT)

Roger Bohn (UC San Diego)

Gerard Cachon (University of  
Pennsylvania)

Morris Cohen (University of  
Pennsylvania)

Sriram Dasu (University of Southern  
California)

Awi Federgruen (Columbia University)

Marshall Fisher (University of  
Pennsylvania)

Art Geoffrion (UCLA)

Steve Graves (MIT)

Vijay Gurbaxani (UC Irvine)

Wallace J. Hopp (Northwestern  
University)

Ananth Iyer (Purdue University)

Sunder Kekre (Carnegie Mellon  
University)

Ton de Kok (Technical University  
Eindhoven)

Panos Kouvelis (Washington University)

Christoph Loch (INSEAD)

Haim Mendelson (Stanford University)

Mohanbir Sawhney (Northwestern  
University)

Avi Seidman (University of Rochester)

Josep Valor (IESE Business School)

Jo van Nunen (Erasmus University)

Garrett van Ryzin (Columbia  
University)

Luk van Wassenhove (INSEAD)

Andrew Whinston (University of Texas,  
Austin)

Candice Yano (UC Berkeley)

## Editorial Scope

**Foundations and Trends<sup>®</sup> in Technology, Information and Operations Management** will publish 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
  - Industrial Equipment
  - Media and Entertainment
  - Process Industries
  - Retailing
  - Telecommunications

### Information for Librarians

Foundations and Trends<sup>®</sup> in Technology, Information and Operations Management, 2007, Volume 2, 4 issues. ISSN paper version 1571-9545. ISSN online version 1571-9553. Also available as a combined paper and online subscription.

Foundations and Trends<sup>®</sup> in  
Technology, Information and Operations Management  
Vol. 2, No. 1 (2007) 1–80  
© 2008 S. M. Disney and M. R. Lambrecht  
DOI: 10.1561/02000000010



## On Replenishment Rules, Forecasting, and the Bullwhip Effect in Supply Chains

Stephen M. Disney<sup>1</sup> and Marc R. Lambrecht<sup>2</sup>

<sup>1</sup> *Logistics Systems Dynamics Group, Cardiff Business School, Cardiff University, Aberconway Building, Colum Drive, Cardiff, CF10 3EU, UK, DisneySM@cardiff.ac.uk*

<sup>2</sup> *Research Center for Operations Management, Katholieke Universiteit Leuven, Naamsestraat 69, 3000 Leuven, Belgium, marc.lambrecht@econ.kuleuven.be*

### Abstract

In this review we focus on supply coordination and use the bullwhip effect as the key example of supply chain inefficiency. We emphasize the managerial relevance of the bullwhip effect and the methodological issues so that both managers and researchers can benefit.

## Contents

---

<b>1</b>	<b>Modern Supply Chains</b>	<b>1</b>
<b>2</b>	<b>The Bullwhip Effect: The Dynamics of Supply Chains</b>	<b>3</b>
2.1	Empirical Evidence of Bullwhip	3
2.2	Causes of the Bullwhip Effect	8
2.3	The Link Between the Bullwhip Effect and Supply Chain Costs	10
<b>3</b>	<b>Methodological Approaches to Studying the Bullwhip Problem</b>	<b>17</b>
3.1	Continuous Time Methods	18
3.2	Discrete Time Methods	20
3.3	Other Approaches	22
<b>4</b>	<b>Replenishment Rules, Forecasting, and the Demand Process</b>	<b>25</b>
4.1	A Smoothing Replenishment Rule for a Stationary i.i.d.	25
4.2	Analysis of the Smoothing Rule Under Stationary Demand	29
4.3	A Smoothing Replenishment Rule Under ARMA(1,1) Demand	35

4.4	The Generalized Out Policy Under ARMA Demand	38
4.5	Minimum Mean Squared Error Forecasting	44
<b>5</b>	<b>Transferring the Inventory Decisions to the Upstream Levels</b>	<b>47</b>
<b>6</b>	<b>Coordination of Replenishment Rules in a Multi-Echelon Setting</b>	<b>51</b>
6.1	The Retailer's Order and Inventory Variance	52
6.2	The Manufacturer's Order and Inventory Variance	53
6.3	The Sequential Optimization Scenario: The Self-Serving Focus	55
6.4	The Global Optimization Problem: Supply Chain Coordination	58
6.5	Linking the Variance Ratios to Costs in the Supply Chain	62
6.6	Practical Considerations	66
6.7	Summary	68
<b>7</b>	<b>New Directions in Bullwhip Research</b>	<b>71</b>
7.1	The Square Root Law for Bullwhip	71
7.2	Multi-Product Scenarios	72
7.3	Stochastic Lead-Times	73
7.4	Multi-Echelon Supply Chain Scenarios	73
7.5	Concluding Remarks	75
	<b>References</b>	<b>77</b>



# 1

---

## Modern Supply Chains

---

Supply chains are networks of firms who pool their capabilities and resources in order to deliver value to the end consumer. Firms are no longer able to own or control complete supply chains. Information technology and modern logistics capabilities have created a global market where companies can take advantage of the opportunity to source internationally [51]. Companies have thus specialized and “partnered” globally with other companies. These companies have then to increasingly focus on logistics and supply chain coordination. Such coordination is now an essential business process.

Modern supply chain management starts with the premise that supply chain members are primarily concerned with optimizing their own objectives and this self-serving focus often results in poor performance. Another way of saying this is that a sequence of local optimum policies does not bring about a globally optimum solution [12]. Munson et al. [68] summarize it as follows “When each member of a group tries to maximize his or her own benefit without regard to the impact on other members of the group, the overall effectiveness may suffer. Such inefficiencies often creep in when rational members of supply chains optimize individually instead of coordinating their efforts.”

## 2 *Modern Supply Chains*

A well known example of such inefficiency is the bullwhip effect. This effect refers to the tendency of replenishment orders to increase in variability as one moves up the supply chain from retailer to manufacturer. A disintegrated material flow, combined with distorted demand information and a lack of replenishment rule alignment inevitably results in poor supply chain dynamics. This lack of coordination may even outweigh the benefits from specialization and economies of scale.

In this review we focus on supply coordination and use the bullwhip effect as the key example of supply chain inefficiency. We emphasize the managerial relevance of the bullwhip effect and the methodological issues so that both managers and researchers can benefit.

## References

---

- [1] L. C. Alwan, J. J. Liu, and Y. Dong-Qing, “Stochastic characterization of upstream demand processes in a supply chain,” *IIE Transactions*, vol. 35, pp. 207–219, 2003.
- [2] F. M. Asl and A. G. Ulsoy, “Analysis of a system of linear delay differential equations,” *Journal of Dynamic Systems, Measurement and Control*, vol. 125, pp. 215–222, 2003.
- [3] K. J. Åström, *Control System Design*. 2005. Preprint, <http://www.cds.caltech.edu/~murray/courses/cds101/fa02/caltech/astrom.html>, Verified 17th September 2005.
- [4] Y. Aviv, “A time-series framework for supply-chain inventory management,” *Operations Research*, vol. 51, no. 2, pp. 210–227, 2003.
- [5] A. Balakrishnan, J. Geunes, and M. Pangburn, “Coordinating supply chains by controlling upstream variability propagation,” *Manufacturing and Service Operations Management*, vol. 6, no. 2, pp. 163–183, 2004.
- [6] J. W. M. Bertrand, “Balancing production level variations and inventory variations in complex production systems,” *International Journal of Production Research*, vol. 24, no. 5, pp. 1059–1074, 1986.
- [7] R. N. Boute, S. M. Disney, M. Lambrecht, and B. Van Houdt, “An integrated production and inventory model to dampen upstream demand variability in the supply chain,” *European Journal of Operational Research*, vol. 178, no. 1, pp. 121–142, 2007.
- [8] R. N. Boute and M. R. Lambrecht, “Altruistic behaviour in supply chain management,” *Tijdschrift voor Economie en Management*, vol. 52, pp. 499–513, September 2007.

78 *References*

- [9] G. E. P. Box and G. M. Jenkins, *Time Series Analysis Forecasting and Control*. San Francisco: Holden-Day, 1970.
- [10] J. R. Buck and T. W. Hill, "Laplace transforms for the economic analysis of deterministic problems in engineering," *The Engineering Economist*, vol. 16, no. 4, pp. 247–263, 1971.
- [11] J. Butman, "A pain in the (supply) chain," *Harvard Business Review*, vol. 80, no. 5, pp. 31–44, 2002.
- [12] G. Cachon, "Supply chain coordination with contracts," in *Supply Chain Management: Design, Coordination and Operations*, (A. de Kok and S. Graves, eds.), pp. 229–339, 2003.
- [13] G. Cachon and M. Fisher, "Campbell soup's continuous product replenishment program: Evaluation and enhanced decision rules," *Production and Operations Management*, vol. 6, pp. 266–276, 1997.
- [14] D. C. Chatfield, J. G. Kim, T. P. Harrison, and J. C. Hayya, "The bullwhip effect ~ Impact of stochastic lead time, information quality, and information sharing: A simulation study," *Production and Operations Management*, vol. 13, no. 4, pp. 340–353, 2004.
- [15] F. Chen and R. Samroengraja, "The stationary beer game," *Production and Operations Management*, vol. 9, no. 1, pp. 19–30, 2000.
- [16] Y. F. Chen and S. M. Disney, "The myopic order-up-to policy with a feedback controller," *International Journal of Production Research*, vol. 45, no. 2, pp. 351–368, 2007.
- [17] Y. F. Chen, Z. Drezner, J. K. Ryan, and D. Simchi-Levi, "Quantifying the Bullwhip effect in a simple supply chain: The impact of forecasting, lead-times and information," *Management Science*, vol. 46, pp. 436–443, 2000.
- [18] P. Childerhouse, J. Aitken, and D. R. Towill, "Analysis and design of focused demand chains," *Journal of Operations Management*, vol. 20, pp. 675–689, 2002.
- [19] M. Christopher and D. R. Towill, "Developing market specific supply chain strategies," *International Journal of Logistics Management*, vol. 13, no. 1, pp. 1–14, 2002.
- [20] R. M. Corless, "The Lambert W function," <http://www.cecm.sfu.ca/publications/organic/rutgers/node34.html>, Verified July, 2004.
- [21] R. M. Corless, G. H. Gonnet, D. E. G. Hare, D. J. Jeffrey, and D. E. Knuth, "On the Lambert W function," *Advances in Computational Mathematics*, vol. 5, pp. 329–359, 1996.
- [22] R. Croson and K. Donohue, "Experimental economics and supply-chain management," *Interfaces*, vol. 32, no. 5, pp. 74–82, 2002.
- [23] R. Croson and K. Donohue, "Impact of POS data sharing on supply chain management: An experimental study," *Production and Operations Management*, vol. 12, no. 1, pp. 1–11, 2003.
- [24] J. Dejonckheere, S. M. Disney, M. R. Lambrecht, and D. R. Towill, "Measuring and avoiding the bullwhip effect: A control theoretic approach," *European Journal of Operational Research*, vol. 147, no. 3, pp. 567–590, 2003.
- [25] J. Dejonckheere, S. M. Disney, M. R. Lambrecht, and D. R. Towill, "The impact of information enrichment on the bullwhip effect in supply chains: A control

- engineering perspective,” *European Journal of Operational Research*, vol. 153, no. 3, pp. 727–750, 2004.
- [26] S. M. Disney, *The Production and Inventory Control Problem in Vendor Managed Inventory Supply Chains*. PhD thesis, Cardiff University, Wales, 2001.
- [27] S. M. Disney, Y. F. Chen, W. Van de Velde, R. Warburton, G. Gaalman, M. Lambrecht, and D. R. Towill, “Economics of the bullwhip effect,” *Annual INFORMS International Conference*, Hong Kong, June 25–28 2006.
- [28] S. M. Disney, I. Farasyn, M. Lambrecht, D. R. Towill, and W. Van de Velde, “Taming the bullwhip effect whilst watching customer service in a single echelon of a supply chain,” *European Journal of Operational Research*, vol. 173, pp. 151–172, 2006.
- [29] S. M. Disney, I. Farasyn, M. R. Lambrecht, D. R. Towill, and W. Van de Velde, “Controlling bullwhip and inventory variability with the golden smoothing rule,” *European Journal of Industrial Engineering*, vol. 1, no. 3, pp. 241–265, 2007.
- [30] S. M. Disney and R. W. Grubbström, “The economic consequences of a production and inventory control policy,” *International Journal of Production Research*, vol. 42, no. 17, pp. 3419–3431, 2004.
- [31] S. M. Disney, M. Lambrecht, D. R. Towill, and W. Van de Velde, “The value of coordination in a two echelon supply chain: Sharing information, policies and parameters,” *IIE Transactions*, vol. 40, no. 3, pp. 341–355, 2008.
- [32] S. M. Disney, P. McCullen, and R. J. Saw, “Dynamic supply chain design: Square root law for bullwhip,” in *Proceedings of the International Symposium on Logistics*, China: Beijing, July 9–12 2006.
- [33] S. M. Disney and M. M. Naim, “Improving the effectiveness of supply chains,” in *15th International Conference on Production Research*, pp. 637–640, Limerick, August 1999.
- [34] S. M. Disney, M. M. Naim, and A. Potter, “Assessing the impact of e-business on supply chain dynamics,” *International Journal of Production Economics*, vol. 89, no. 2, pp. 109–118, 2004.
- [35] S. M. Disney, D. R. Towill, and W. Van de Velde, “Variance amplification and the golden ratio in production and inventory control,” *International Journal of Production Economics*, vol. 90, no. 3, pp. 295–309, 2004.
- [36] M. Fliess, R. Marquez, and H. Mounier, “An extension of productive control, PID regulators and smith predictors to some linear delay systems,” *International Journal of Control*, vol. 75, pp. 728–743, 2002.
- [37] J. Forrester, *Industrial Dynamics*. USA, Cambridge, MA: MIT Press, 1961.
- [38] G. Gaalman and S. M. Disney, “State space investigation of the bullwhip problem with ARMA(1,1) demand processes,” *International Journal of Production Economics*, vol. 104, no. 2, pp. 327–339, 2006.
- [39] G. Gaalman and S. M. Disney, “On bullwhip in a family of Order-Up-To policies with ARMA(2,2) demand and arbitrary lead-times,” Accepted for publication in the *International Journal of Production Economics*, <http://dx.doi.org/10.1016/j.ijpe.2006.11.024>, 2007.

80 References

- [40] G. Gaalman and S. M. Disney, "On the echelon-order-up-to policy: A stochastic optimal control approach," in *Manufacturing and Service Operations Management Conference*, Beijing, June 18–19 2007.
- [41] S. C. Graves, "A single-item inventory model for a non-stationary demand process," *Manufacturing and Service Operations Management*, vol. 1, no. 1, pp. 50–61, 1999.
- [42] R. W. Grubbström, "On the application of the Laplace transform to certain economic problems," *Management Science*, vol. 13, no. 7, pp. 558–567, 1967.
- [43] J. H. Hammond, "Barilla SpA(A)," in *Harvard Business School Case 6-694-046*, Boston, MA, 1994.
- [44] K. Hoberg, J. R. Bradley, and U. W. Thonemann, "Analysing the effect of the inventory policy on order and inventory variability with linear control theory," *European Journal of Operational Research*, vol. 176, no. 3, pp. 1620–1642, 2007.
- [45] W. Holland and M. S. Sodhi, "Quantifying the effect of batch size and order errors on the bullwhip effect using simulation," *International Journal of Logistics Research and Applications*, vol. 7, no. 3, pp. 251–261, 2004.
- [46] H. Holweg, S. M. Disney, J. Holmström, and J. Småros, "Supply chain collaboration: Making sense of the strategy continuum," *European Management Journal*, vol. 23, no. 2, pp. 170–181, 2005.
- [47] T. Hosoda, *The Principles Governing the Dynamics of Supply Chains*. PhD thesis, Cardiff University, UK, 2005.
- [48] T. Hosoda and S. M. Disney, "The governing dynamics of supply chains: The impact of altruistic behavior," *Automatica*, vol. 42, pp. 1301–1309, 2006.
- [49] T. Hosoda and S. M. Disney, "The impact of market demand mis-specification on a two-level supply chain," under review at the *International Journal of Production Economics*, 2008.
- [50] D. Hoyt, "Solectron: From contract manufacturer to global supply chain integrator," in Stanford University Graduate School of Business, *Case GS-24*, Stanford, CA, 2001.
- [51] IBM Business Consulting Services, *The Specialized Enterprise: A Fundamental Redesign of Firms and Industries*, p. 21. 2005.
- [52] F. R. Jacobs, "Playing the beer distribution game over the internet," *Production and Operations Management*, vol. 9, no. 1, pp. 31–39, 2000.
- [53] E. I. Jury, *Theory and Application of the Z-Transform Method*. New York: Robert E. Krieger Publishing Company, 1964.
- [54] R. E. Kalman, "A new approach to linear filtering and prediction problems," *Transactions of the ASME-Journal of Basic Engineering*, vol. 82, no. Series D, pp. 35–45, 1960.
- [55] H.-K. Kim and J. K. Ryan, "The cost impact of using simple forecasting techniques in a supply chain," *Naval Research Logistics*, vol. 50, pp. 388–411, 2003.
- [56] J. G. Kim, D. C. Chatfield, T. P. Harrison, and J. C. Hayya, "Quantifying the bullwhip effect in a supply chain with stochastic lead time," *European Journal of Operational Research*, vol. 173, pp. 617–636, 2006.
- [57] S. Konicki, "Now in bankruptcy, Kmart struggled with supply chain," *Information Week*, <http://www.informationweek.com/story/IWK20020125S0020> Verified on 28th January, 2002.

- [58] A. Kuper and D. Branvold, "Innovation diffusion at Hewlett Packard," in *Supply Chain Management: Innovations for Education*, (M. E. Johnson and D. F. Pyke, eds.), pp. 205–218, FL: Miami, 2000.
- [59] D. A. Lam and J. A. Miron, "The effects of temperature on human fertility," *Demography*, vol. 33, no. 3, pp. 291–305, 1996.
- [60] C. C. Lee and W. H. J. Chu, "Who should control inventory in a supply chain?," *European Journal of Operational Research*, vol. 164, pp. 158–172, 2005.
- [61] H. L. Lee, V. Padmanabhan, and S. Whang, "The bullwhip effect in supply chains," *Sloan Management Review*, vol. 38, no. 3, pp. 93–102, 1997.
- [62] H. L. Lee, V. Padmanabhan, and S. Whang, "Information distortion in a supply chain: The bullwhip effect," *Management Science*, vol. 43, no. 4, pp. 546–558, 1997.
- [63] H. L. Lee, V. Padmanabhan, and S. Whang, "Comments on "information distortion in a supply chain: The bullwhip effect" The bullwhip effect: A reflection," *Management Science*, vol. 50, no. 12, pp. 1887–1893, 2004.
- [64] A. Looman, F. A. J. Ruttins, and L. de Boer, "Designing ordering and inventory management methodologies for purchased parts," *Journal of Supply Chain Management*, vol. 38, no. 12, pp. 22–29, 2002.
- [65] J. A. D. Machuca and R. P. Barajas, "A computerized network version of the beer game via the Internet," *Systems Dynamic Review*, vol. 13, no. 4, pp. 323–340, 1997.
- [66] D. H. Maister, "Centralisation of inventories and the 'Square Root Law'," *International Journal of Physical Distribution*, vol. 6, no. 3, pp. 124–134, 1976.
- [67] S. Makridakis, A. Andersen, R. Carbone, R. Fildes, M. Hibon, R. Lewandowski, J. Newton, R. Parzen, and R. Winkler, "The accuracy of extrapolation (time series) methods: Results of a forecasting competition," *Journal of Forecasting*, vol. 1, pp. 11–153, 1982.
- [68] C. L. Munson, J. Hu, and M. Rosenblatt, "Teaching the costs of uncoordinated supply chains," *Interfaces*, vol. 33, no. 3, pp. 24–39, 2003.
- [69] N. H. Mustafa and S. M. Disney, "Approaches to solving the inventory routing problem," in *EUROMA International Conference on Operations and Global Competitiveness*, pp. 767–774, Budapest: Hungary, June 19–22 2005.
- [70] J. F. Muth, "Optimal properties of exponentially weighted forecasts," *Journal of the American Statistical Association*, vol. 55, pp. 299–306, 1960.
- [71] G. Ortmeyer, J. Quelch, and W. Salmon, "Restoring credibility to retail pricing," *Sloan Management Review*, vol. Fall, pp. 55–66, 1991.
- [72] Y. Ouyang and C. Daganzo, "Characterization of the bullwhip effect in linear, time-invariant supply chains: Some formulae and tests," *Management Science*, vol. 52, no. 10, pp. 1544–1556, 2006.
- [73] B. Peleg, "STMicroelectronics e-chain optimization project: Achieving streamlined operations through collaborative forecasting and inventory management," in *Stanford Global Supply Chain Management Forum Case*, Stanford, CA: Stanford University, 2003.
- [74] A. Potter and S. M. Disney, "Bullwhip and batching: An exploration," *International Journal on Production Economics*, vol. 104, no. 2, pp. 408–418, 2006.

82 *References*

- [75] A. Sadeghi and S. M. Disney, "Quantifying the bullwhip effect in a two product supply chain," Working paper, Cardiff University, UK: Cardiff Business School, 2007.
- [76] E. A. Silver, D. F. Pyke, and R. Peterson, *Inventory Management and Production Planning and Scheduling*. New York, USA: John Wiley and Sons, 1998.
- [77] D. Simchi-Levi, P. Kaminsky, and E. Simchi-Levi, *Designing and Managing the Supply Chain: Concepts, Strategies and Case Studies*. McGraw-Hill International Edition, 1998.
- [78] H. Simon, "On the application of servomechanism theory in the study of production control," *Econometrica*, vol. 20, pp. 247–268, 1952.
- [79] O. J. Smith, "A controller to overcome dead time," *Instrument Society of America — Journal*, vol. 6, no. 2, pp. 28–33, 1959.
- [80] J. D. Sterman, "Modelling managerial behaviour: Misperceptions of feedback in a dynamic decision making experiment," *Management Science*, vol. 35, no. 3, pp. 321–339, 1989.
- [81] D. R. Towill, "1961 and all that: The influence of Jay Forrester and Jack Burbidge on the design of modern manufacturing systems," in *Proceedings of the 1994 International Systems Dynamics Conference on Business Decision Making*, pp. 105–115, Stirling, 1994.
- [82] D. R. Towill, M. R. Lambrecht, S. M. Disney, and J. Dejonckheere, "Explicit filters and supply chain design," *Journal of Purchasing and Supply Management*, vol. 9, no. 2, pp. 73–81, 2003.
- [83] Y. Z. Tsympkin, "Theory of pulse systems," (in Russian), Moscow: State Press for Physics and Mathematical Literature, 1958.
- [84] Y. Z. Tsympkin, *Sampling Systems Theory and its Application*, Vol. 2. Oxford: Pergamon Press, 1964.
- [85] A. Tustin, "The effects of backlash and of speed-dependent friction on the stability of closed-cycle control systems," *Journal of the IEE Part IIA*, vol. 94, pp. 143–151, 1947.
- [86] A. Tustin, "A method of analysing the behaviour of linear systems in terms of time series," *Journal of the IEE Part IIA*, vol. 94, pp. 130–142, 1947.
- [87] A. Tustin, "A method of analysing the effect of certain kinds of non-linearity in closed-cycle control systems," *Journal of the IEE Part IIA*, vol. 94, pp. 152–160, 1947.
- [88] A. Tustin, "The nature of the operator's response in manual control and its implementations for controller design," *Journal of the IEE Part IIA*, vol. 94, pp. 190–202, 1947.
- [89] C. Van Horne and P. Marier, "The Quebec wood supply game: An innovative tool for knowledge management and transfer," available for download at <http://forac.fsg.ulaval.ca/fileadmin/docs/Publications/QCWoodSupplyGame.pdf>, 2007.
- [90] H. J. Vassian, "Application of discrete variable servo theory to inventory control," *Journal of the Operations Research Society of America*, vol. 3, no. 3, pp. 272–282, 1955.



- [91] R. D. H. Warburton and S. M. Disney, “Order and inventory variance amplifications: The equivalence of discrete and continuous time analysis,” *International Journal of Production Economics*, vol. 110, pp. 128–137, 2007.
- [92] X. Zhang, “The impact of forecasting methods on the bullwhip effect,” *International Journal Production Economics*, vol. 88, pp. 15–27, 2004.
- [93] P. H. Zipkin, *Foundations of Inventory Management*. New York, USA: McGraw-Hill, 2000.