Chair of Logistics and Supply Chain Management

040051 KFK PM/SCM/TL:

Seminar A (E)

4 ECTS points

"Advances in Inventory Management"

Lecturer: Univ. Prof. Dr. Heinrich Kuhn

Spring Semester 2013

List of Themes

Course Description

This course involves fundamental and advanced models and solution approaches for inventory management which is one of the core drivers for success in supply chain management. Inventory management has gained much attention in the scientific community and in industrial practice. The course focuses on new techniques and results of outstanding research works dealing with advanced and applied inventory models. The students will learn to write a research oriented term paper related to scholarly manuscripts in leading journals in the area of production, logistics, operations management, and operations research. The students have to select one specific inventory problem out of a pre-given list of themes of inventory problems. In addition, the students will learn to present and to defend their findings during a class room sessions. In this way, students will learn concepts and models for various modern inventory systems. These systems include single- and multi-level, and stationary and one-period stochastic inventory models. The students are expected to read the main references before the class and to participate in class room discussions. In addition, students are expected to prepare two tutorial sessions on fundamental issues or modeling approaches in inventory theory.

The course is designed for master students who are interested in advanced methods for analyzing inventory system. The course includes short tutorials given by the students, i.e., overviews on fundamental approaches in analyzing inventory systems, class discussion, tutorial slides (max. 10 slides per tutorial), a written term paper on one specific topic on inventory management (15 – 20 pages), and presentations that are based on the term paper; approx. 20 minutes.

List of Themes

Fundamentals of Inventory Management

1. Analyzing the effect of stochastic replenishment lead times on safety stocks in inventory systems

In many classical inventory models it is common to assume that the replenishment lead times are deterministic. However, the supplier behavior in practice show that most supplier deliver their orders with random lead times. Reasons for that are stochastic processing, stochastic transportation, and stochastic handling times, etc. Stochastic replenishment lead times influence the distribution of the demand during lead time and thus this may influence the necessary safety stocks in an inventory system. Aim of the seminar work is to analyze factors which influence the demand during lead time (demand during the risk period) in single level inventory systems. Possible approaches to approximate the distribution of the demand during lead time should be presented and numerical examples for a selected inventory policy should be analyzed.

Literature

Eppen, G. and R. Martin, Determining safety stock in the presence of stochastic lead time demand, in: Management Science, Vol. 34, 1988, pp. 1380-1390.

Lau, A.H.L. and H.-S. Lau, A comparison of different methods for estimating the average inventory level in a (Q,R) system with backorders, International Journal of Production Economics (IJPE), Vol. 79, No. 3, 2002, pp 303-316.

Park, C., An analysis of the lead time demand distribution derivation in stochastic inventory systems, International Journal of Production Economics (IJPE), Vol. 105, No. 1, 2007, pp. 263-272

Suchanek, B. Sicherheitsbestände zur Einhaltung von Servicegraden, Frankfurt (Peter Lang) 1996.

Tempelmeier, H., Inventory Management in Supply Networks: Problems, Models, Solutions Norderstedt: Books on Demand, 2011, Chapter B.3.5.

2. Inventory management for products in their end-of-life cycle

At the end-of-production (EOP) of a certain product, component or part customers are offered an opportunity to place a so-called final order for these parts which are usually used as spare part for the related machines, facilities, automotives, etc. The seminar work should present, analyze and discuss an applicable model for the base case of one customer with one machine. The customer plans to use this machine up to a fixed horizon. Based on this horizon, and on the failure rates of the components, the prices of spare components, and the consequences of the machine failing before the critical lifetime is reached, the size of the final order has to be determined.

Literature

Teunter, R.H. and L. Foruin, End-of-life service: A case study. European Journal of Operational Research (EJOR), Vol. 107, No. 1, 1998, pp. 19-34.

Teunter, R.H. and W.K.K. Haneveld, Inventory control of service parts in the final phase. European Journal of Operational Research (EJOR), 137, No. 3, 2002, pp 497-511.

Teunter, R.H. and W.K.K. Haneveld, The “final order” problem, European Journal of Operational Research (EJOR), Vol. 107, No. 1, 1998, pp. 35-44.

Song, J.-S. and P.H. Zipkin, Managing Inventory with the Prospect of Obsolescence. Operations Resarch (OR), Vol. 44, No. 1, 1993, pp. 215-222.

3. Customer waiting times in single-product, single-level (r,S) inventory systems

From a customer perspective the distribution of the customer waiting time is one of most relevant service criteria in inventory systems. The distribution of customer waiting times has been analyzed for various continuous and periodic review inventory systems, where the relevant studies mainly differ in terms of the chosen replenishment policy, and whether they consider waiting times per unit or per order. In industrial applications the periodic review order-up-to (r,S) inventory policy seems to be the most adequate inventory policy. Thus, the task of the seminar work is to describe, to analyze, and to discuss analytical models for analyzing the customer waiting times in a single-level (r, S) inventory systems.

Literature

Fischer, L., Bestandsoptimierung für das Supply Chain Management, Norderstedt (Books on Demand) 2010.

Tempelmeier, H., Inventory Management in Supply Networks: Problems, Models, Solutions Norderstedt: Books on Demand, 2011.

Tempelmeier, H., Inventory service-levels in the customer supply chain, OR Spectrum (ORS), Vol. 22, No. 3, 2000, pp. 361–380.

Wensing, T., Periodic Review Inventory Systems. Berlin: Springer, 2011

Wensing, T. and H. Kuhn, Analysis of a multi-component periodic review inventory system in an assembly environment, in: OR Spectrum, April 2012, DOI: 10.1007/s00291-012-0295-2.

4. Modeling stochastic replenishment lead times in inventory systems with order crossovers

Most works on the analysis of inventory systems assume that replenishment orders arrive in the same sequence in which they were issued. However, it can be theoretically shown and also observed in practice that this is not necessarily the case if multiple parallel sources are involved in the order fulfillment process. In that situation, the order arrival sequence will differ from the order issue sequence, whenever an order's lead time exceeds the next order's lead time plus the headstart given by the former's earlier issue date. This phenomenon is referred to as order crossover in the literature.

The term paper should review the main techniques for investigating the crossover phenomenon. The application of these techniques should be demonstrated when analyzing an (r,S) inventory system. The effect of crossovers on the replenishment process as well as the error that is observed when neglecting the phenomenon should be illustrated by numerical examples.

Literature

Riezebos, J., Inventory Order Crossovers. International Journal of Production Economics (IJPE), Vol. 104, No. 2, 2006, pp. 666–675.

Wensing, T., Periodic Review Inventory Systems. Berlin: Springer, 2011

Wensing, T. and H. Kuhn, Analysis of Production and Inventory Systems, When Orders May Cross Over, Working Paper, Catholic University of Eichstaett-Ingolstadt, June 2012.

Zipkin, P.H., Stochastic Leadtimes in Continuous-Time Inventory Models. Naval Research Logistics Quarterly (NRL), Vol. 33, No. 1, 1986, N0. 4., pp. 763-774.

Inventory Management in Retail

5. Determining safety stocks in inventory systems assuming lost sales

In retail industry a customer who is willing to purchase a product and is faced with an out-of-stock or an out-of-shelve situation in the store has several possibilities to react. He/she can delay the purchase, buy another product (a substitution), buy the product in another store, or not buy the product at all. Empirical studies show that only 15% of all customers delay the purchase if they are faced with a stock-out for their preferred product in a particular store. Thus, in all other cases the demand for the preferred product–store combination is lost. While lost sales systems are very relevant in practice, most scientific papers on stochastic inventory models assume back-ordering. The reason for the limited attention for lost sales systems in literature is the fact that inventory models with lost sales are difficult to analyze. Thus, appropriate heuristic methods are relevant for retail praxis. The seminar work should present, discuss, and analyze inventory models assuming the lost sales case.

Bijvank, M. and I.F.A. Vis, Lost-sales inventory theory: A review, European Journal of Operational Research (EJOR), Vol. 215, No. 1, 2011, pp. 1–13.

van Donselaar K.H. and R.A.C.M. Broekmeulen, Determination of safety stocks in a lost sales inventory system with periodic review, positive lead-time, lot-sizing and a target fill rate, International Journal of Production Economics (IJPE), in Press, available online since 26 May 2011.

van Donselaar, K.H., A.G. de Kok, and W.G.M.M. Rutten, Two replenishment strategies for the lost sales inventory model: a comparison. International Journal of Production Economics (IJPE), Vol. 46, No. 47, 1996, pp. 285-295.

Zipkin, P., Old and new methods for lost-sales inventory systems. Operations research (OR), Vol. 56, No. 5, 2008, pp. 1256-1263.

6. Optimization the order packaging unit in a two-echelon distribution system

The order packaging unit or ship-pack defines the number of consumer units that are combined to one order and distribution unit for supplying the individual stores in retail industry. In general the inventory models applied in retailing assume a fixed pack sizes which is equivalent to the smallest possible order quantity and, consequently, the order sizes have to be an integer multiple of this quantity. However, the order packaging unit of an item has great implications for its average and maximum inventory in the individual retail stores. Thus, modeling approaches are relevant assuming a variable order packing unit. Applying these approaches for a particular item the optimal pack size that is to be shipped from the distribution center (DC) to the retail stores can be determined. The seminar work should present, discuss and analyze an appropriate modeling and solution approach for this planning issue.

Literature:

Kuhn H. and M. Sternbeck, Integrative Retail Logistics: An Exploratory Study, forthcoming in: Operations Management Research, forthcoming 2013.

Wen, N., S. C. Graves, and J. Z. Ren, Ship-pack optimization in a two-echelon distribution system, European Journal of Operational Research (EJOR), Vol. 220, No. 3, 2012, pp. 777-785.

7. Inventory management for perishable items in grocery supply chains

Several products in grocery stores exhibit a sell-by day. This has to be considered when determining the order size or the inventory level of the products in the retail distribution centers and the retail stores. However, many inventory control models for perishable items assume no lead-time, no lot-sizing, stationary demand, a first in first out withdrawal policy, and/or product life time equal to two periods. These assumptions are in general to restrictive if these models have to be applied in retail praxis. Aim of the seminar work is to present and to discuss more realistic modeling and solution approaches. Examples and numerical results should be presented.

Literature

Akkerman, R., P. Farahani, and M. Grunow, Quality, safety and sustainability in food distribution: A review of quantitative operations management approaches and challenges. OR Spectrum (ORS), Vol. 32, No. 4, 2010, pp. 863- 904.

Bakker, M., J. Riezebos, and R.H. Teunter, Review of inventory systems with deterioration since, European Journal of Operational Research (EJOR), Vol. 221, No. 2, 2012, pp. 275-284.

Broekmeulen, R.A.C.M. and K.H. van Donselaar, A heuristic to manage perishable inventory with batch ordering, positive lead-times, and time-varying demand. Computers & Operations Research (COR), Vol. 36., No. 11, 2009, pp. 3013-3018.

Minner, S. and S. Transchel, Periodic review inventory-control for perishable products under service-level constraints, in: OR-Spectrum (ORS), Vol. 32., No. 4., 2010, pp. 979-996.

van Donselaar, K.H., T. van Woensel, R.A.C.M. Broekmeulen, and J.C. Fransoo, Inventory control of perishables in supermarkets. International Journal of Production Economics (IJPE), Vol. 104, No. 2, 2006, pp. 462-472.

van Woensel, T., K.H. van Donselaar, R.A.C.M. Broekmeulen, and J.C. Fransoo, Consumer responses to shelf-out-of-stocks of perishable products. International Journal of Physical Distribution and Logistics Management (IJPDLM), Vol. 37. No. 9, 2007, pp. 704-718.

8. Multi-product newsboy problem with an inventory constraint

In several cases in real life it is advisable to store products only for a specific period of time since at a certain time the products become worthless or can only be sold allowing a very high discount, e.g. newspapers, Christmas trees, fashion articles or other seasonal products. The problem is known in literature as newsvendor problem, newsboy problem, or Christmas tree problem and presented in several standard operational management textbooks. However, in some cases budget or inventory space constraints have to be considered. Assuming these circumstances and a multi-product situation the optimal order size of one product cannot be solved independent of the order sizes of the other products, thus, the multi-product newsboy problem results. Task of the seminar work is to present a modeling and solution approach of the multi-product newsboy problem considering an inventory constraint. An overview on related problems and modeling approaches should be given. In addition, a certain number of problem instances should be implemented and solved by an appropriate solution algorithm. Furthermore, the numerical results of the solution approach should be presented and discussed.

Literature

Abdel-Malek, L.L. and R. Montanari, An analysis of the multi-product newsboy problem with a budget constraint., in: International Journal of Production Economics (IJPE), Vol. 97, No. 3, 2005; pp. 296-307.

Abdel-Malek, L.L. and R. Montanari, On the multi-product newsboy problem with two constraints. Computers & Operations Research (COR), Vol. 32, No. 8, 2005; pp. 2095-2116.

Chen, L-H and Y.-C. Chen, A multi-item budget-constraint newsboy problem with a reservation policy, in: Omega, Vol. 38, No. 6, 2010, pp. 431-439.

Lau, H.S. and A.H.L. Lau, The multi-product multiconstraint Newsboy problem: Applications formulation and solution. Journal of Operations Management (JOM), Vol. 13, 1995, pp. 153–162.

Silver, E.A., D.F. Pyke, and R. Peterson, Decision Systems for Inventory Management and Production Planning, 3. Ed., New York (Wiley) 1998.

Tempelmeier, H., Inventory Management in Supply Networks: Problems, Models, Solutions, Norderstedt (Books on Demand) 2011, Chapter C.2.1.

Inventory Management and Queuing Systems– Methodical Insights

9. Modeling inventory systems using a discrete Markov chain in continuous time

Several classical inventory systems can be analyzed using Markov chains or queuing models. Aim of the seminar work is to demonstrate these modeling approaches by some selected inventory policies. First, it should be demonstrated how the classical (s,q) inventory policy could be modeled using a discrete Markov chain in continuous time. Afterwards, the resulting model should be modified so that the new model represents a base-stock-policy. In addition, one more applicable inventory policy should be implemented and analyzed.

Literature

Tempelmeier, H., Inventory Management in Supply Networks: Problems, Models, Solutions Norderstedt (Books on Demand) 2011, Chapter C.2.2 and C.2.3.

Kiesmüller, G.P.; A.G. de Kok, and S. Dabia, Single item inventory control under periodic review and a minimum order quantity Original Research Article, International Journal of Production Economics (IJPE), Vol. 133, No. 1, 2011, pp. 280-285.

10. Lot sizing to minimize flow times

Lot sizing models usually assume cost oriented goal functions. The aim of these models is in general to minimize the sum of setup cost and inventory holding cost.

In literature this approach is often criticized since on a short term planning level setup and inventory holding cost cannot be economically rationalized. Alternatively, technical target values are formulated; e.g., minimizing production flow time, maximizing equipment utilization, or minimizing lateness or tardiness. These goal functions reflect much better the real situation on the shop floor than cost oriented target values.

A specialized group of lot sizing models aim to minimize lead times and/or in-process inventories (work in process) assuming stochastic conditions, i.e., stochastic order arrivals and stochastic processing times. The production system is then modeled by a single or multiple server queuing system.

The aim of the seminar work is to clarify the fundamental planning problem and the particular assumptions of this class of lot sizing models. The applicability in practice should be discussed and illustrated by some examples. Several instances should be analyzed and numerical results should be presented.

Literature

Karmarkar, U. S., Lot sizes, lead times and in-process inventories, Management Science, Vol. 33, 1987, pp. 409–418.

Karmarkar, U.S., Batching to minimize flow times on parallel heterogeneous machines, Management Science, Vol. 35, 1989, pp. 607–613.

Karmarkar, U.S., S. Kekre, and S: Kekre, Lot sizing in multi-item multi-machine job shops, in: IIE Transactions, Vol. 17, 1985, pp. 290–298.

Lambrecht, M.R. and N.J. Vandaele, A general approximation for the single product lot sizing model with queueing delays, European Journal of Operational Research (EJOR), Vol. 95, No. 1, 1996, pp. 73-88.

Lambrecht, M.R., S. Chen, and N.J. Vandaele, A lot sizing model with queueing delays: The issue of safety time, European Journal of Operational Research (EJOR), Vol. 89, No. 2, 1996, pp. 269-276.

Zimmermann, G., Quantifizierung der Bestimmungsfaktoren von Durchlaufzeiten und Werkstattbeständen , Zeitschrift für Betriebswirtschaft (ZfB), Vol. 54, 1984, pp. 1016-1032.

Templemeier, H., Supply Chain Management und Produktion, 2nd ed., Nordersted (Books on Demand) 2005, pp. 224-235.

11. Modeling volume dependent replenishment lead times using queuing models

Classical inventory models assume independent deterministic or stochastic replenishment lead times. However, if the production capacity of the supplier is limited, the lead time of a replenishment order depends on the number of open orders. The underlying assumptions of the inventory system can be modeled by a single stage queuing system. Aim of the seminar work is to describe and to discuss this modeling approach and to analyze how the limited capacity influences the safety stock that must be held at the customer site. The modeling approach should be implemented and some instances should be analyzed using the achieved numerical results of this modeling approach.

Literature

Buzacott, J.A. and J.G. Shanthikumar, Stochastic Models of Manufacturing Systems, Englewood Cliffs (Prentice Hall) 1993, Chapter 4.3.

Kuhn, H., Bestimmung der Anzahl Karten in einem KANBAN-System, Wirtschaftswissenschaftliches Studium (WISU), Vol. 23, No. 6, 1994, pp. 527-532.

Kuhn, H., Optimaler Lagerbestand in einem KANBAN-System (Fallstudie), Wirtschaftswissenschaftliches Studium (WISU), Vol. 23, No. 7, 1994, pp.618-620.

Tempelmeier, H., Inventory Management in Supply Networks: Problems, Models, Solutions Norderstedt (Books on Demand), 2011, Chapter C.5.

12. Repairable inventory system

In repairable inventory systems, unlike in classic inventory systems, used or failed items are repaired and returned to useable condition and afterwards restocked in the inventory system. Repairable inventory systems are typically composed of high cost, long-life goods, where it is less expensive to repair an item than it is to replace it. These repairable inventory systems are common in a variety of industrial settings; e.g., aircraft, automotive, copying machines, transportation equipment, and electronics.

The typical problem is concerned with the optimal stocking of the repairable parts and the location of these stocks, given that there may be multiple locations, i.e., local inventory bases and one or several centrally located repair depots. Various models and solution approaches have been developed to solve the problem.

The task of the seminar work is to structure the existing modeling approaches on repairable inventory system. The various models proposed and the major assumptions made in those models should be examined. In addition, one recent suggested modeling approach based on a multi-class closed queuing network should be presented, analyzed and discussed.

Literature

Park C.-W. and H.-S. Lee, A multi-class closed queueing maintenance network model with a parts inventory system, Computers & Operations Research (COR), Vol. 38, No. 11, 2011, pp. 1584-1595

Díaz, A. and M.C. Fu, Models for multi-echelon repairable item inventory systems with limited repair capacity, European Journal of Operational Research (EJOR), Vol. 97, No. 3, 1997, pp. 480-492.

Guide Jr., V.D.R. and R. Srivastava, Repairable inventory theory: Models and applications, European Journal of Operational Research (EJOR), Vol. 102, No. 1, 1997, pp. 1-20.

Muckstadt, J.A. and A. Sapra, Principles of Inventory Management, New York (Springer), 2010, Chapter 8.