Report on the 7th ISIR Summer School on "Supply Chain Inventory Management"

Mannheim Business School, Germany, 14th-19th August 2005

Hosting the seventh ISIR Summer School, the Department of Logistics at Mannheim Business School was pleased to welcome inventory researchers from 13 countries for five days in Mannheim (Germany). The summer school was financially supported by SAP and the University of Mannheim. Professor Stefan Minner (Mannheim) was able to gather a good mix be-tween young doctoral students and senior academics in the broad field of "Supply Chain Inventory Management", among them four distinguished researchers who accepted the invitation to give tutorials in their special field of research interest. Somewhat unexpectedly, in his presentation Edward Silver (Calgary) skipped any inventory-control-related formula and instead gave non-quantitative but practical advice for improving research productivity from his own experience. Tuesday's tutorial given by Charles Corbett (UCLA) focused on the implica-tion of information asymmetry on supply chain issues, followed by an overview on the emerg-ing research in the field of joint pricing and inventory optimization on Wednesday (Moritz Fleischman, Rotterdam). On Thursday, Ton de Kok (Eindhoven) discussed the general case of multi-echelon multi-item inventory models under both stochastic demand and leadtimes. The bulk of presentation time, however, was devoted to doctoral students to discuss ideas and re-sults from their own research projects. According to the successful format of the previous summer schools, each presentation was followed by comments of a fellow Ph.D. student as well as one senior researcher, both of which having been assigned to the complete working paper in advance.

The Summer School proved once again to be valuable beyond mere academic purposes by providing an ideal platform for social networking with interesting people from all over the world. This was promoted by and reflected in a diverse social program with, amongst other activities, an excursion to the beautiful city of Heidelberg on Wednesday. The week's cultural highlight took place already at an early stage of the week when the school's participants visited the castle of Hambach on Tuesday. In a guided tour through and around the castle the participants' obvious thirst for German history was satisfied, and so was the appetite for more basic needs during the conference dinner in the castle's glamorous banqueting hall.

Find below all abstracts of the working papers (in the order of the presentations given) as well as a list of all participants.

Mirko Kremer, Mannheim

Abstracts

Some suggestions for improving research productivity

Edward A. Silver

The speaker has conducted research and published associated write-ups throughout his career which spans more than 40 years. Through literature sources, personal trial and error experiences, and observations of students and other colleagues, he has developed a collection of ideas regarding improving research productivity. Interactive discussion will be encouraged during the session. The topic should be very relevant for Ph.D. students early in their research careers.

On supply chain inventory management utilizing extensions of the multi-product newsboy models

Mojisola Otegbeye, Layek Abdel-Malek

Prudent inventory control strategies are crucial to the efficient performance of today's global supply chains. Both the optimum selection of suppliers and the determination of the lot size provided are among the major contributors to a successful supply chain management. The constrained newsboy problem is found to be one of the appropriate tools for decision making to select vendors and determine order quantities in supply chain environments particularly when companies resort to E-bidding as opposed to long term partnerships. This is because when a company practices E-bidding, it usually orders once for an unknown demand of products and possibly random yields of vendors. In this work, we extend the seminal work of Hadley and Whitin (Analysis of inventory systems, Englewood Cliffs, NJ: Prentice-Hall; 1963) regarding the multi-product newsboy problem with constraints to cover the vendor selection problem as well as random yield situations in supply chain management. In our development, we will utilize the proposed extension to select not only among the competing vendors but, also among the considered products and the amounts of each to render a cost efficient supply chain. Several authors have developed models extending the works by Hadley and Whitin in this area to envelop more complex ordering scenarios of the newsboy model and solution methodologies that are more efficient. Among these models, we note those by Lau and Lau (European Journal of Operational Research, 1996; 94:29-42) and Abdel-Malek, L., Montanari R., (Computers & Operations Research, 2005; 32:2095-2116). However, situations when the quantities requisitioned are not exactly satisfied by the supplier are not sufficiently addressed. One of the early works dealing with such issue is that of Silver, E.A., (INFOR 1976; 14:32-39) where a general EOQ model was used to show that the additional factors influencing the economic order quantity are the mean and standard deviation of the demand. Incorporating Silver's assumptions, Noori A.H., Keller G., (INFOR 1986; 24(1):1-11) extended this problem to the newsboy model and came to the same conclusions. We find these extensions particularly

relevant in today's complex E-bidding and reverse logistics practices, where supplies from vendors and end-of-life products' recoveries are increasingly assuming random variations.

To complement these works, we develop a tractable solution model for the constrained, multi-product newsboy problem with random yield. Then based on the model, we show how to utilize it, subject to various operating constraints, to 1) select vendors, and 2) choose the product mix as well as the optimum amounts of items to be ordered from each where the yield of the suppliers could vary.

A model for transport costs with consolidation effects

Bas Verheijen, R. Kuik

In this paper, we will study transportation tariffs for products which are sharing a capacitated transport resource, such as a truck, traveling from A to B. Transportation costs can be modeled depending on the system and the boundaries of the system under study. When the open market for transportation is studied, partially filled trucks might be shared by other products. This is reflected in the cost function for transportation. Cetinkaya and Bookbinder [2003] describes this as common carriage. In case of an isolated system, where the truck is owned (private carriage) and where multiple products can share the truck, fixed costs per trip are charged. This system can be analyzed by following an optimization procedure -usually heuristic- for the entire system simultaneously (see Russell and Krajewski [1992], Buffa and Munn [1990]). Alternatively, we can analyze a system of a single product which is using common carriage, where transport tariffs are determined by the market.

In this paper, we propose a model for transportation costs which is shaped in such a way that demand from other products in the market for transport capacity is taken into account. Ultimately, each trip is charged fixed costs. Our aim is to show that our model represents a close reflection of actual transport rates in the market and that stocking and transporting decisions for items using this cost function are made similar to a situation in which the entire system was optimized. We propose to model the transportation costs as a stepwise concave negative quadratic step-function with the transport capacity, dependent on the truck capacity. The difference between a step-function per truckload and the new transport function represents the economic value of the remaining capacity in the truck. Unused truck-space may represent value as it could be used to transport other products. The value of the unused space depends on the amount of space available and the transport market. In an environment where demand to fill the remaining capacity in the truck is high, the transport cost function tend towards a function linear with capacity. When the possibility of filling the empty truck space with other goods is small, the cost function approaches a step function, with fixed costs per truck.

This paper has two main contributions. We present a transportation cost function to model the transport cost for one item, such that consolidation opportunities with other products in the market are taken into account. We determine the basic shape and properties of this function. We propose and show support for the use of this function by comparing it to tariffs quoted by third party logistics providers as well as theory. Secondly, we present results of heuristic solutions of the multi-item optimization that support the proposed function.

References:

F. P. Buffa and J. R. Munn. Multi-item grouping algorithm yielding near-optimal logistics

cost. Decision Sciences, 21(1):14⁻34, 1990.

S. Cetinkaya and J. H. Bookbinder. Stochastic models for the dispatch of consolidated shipments. Transportation Research Part B-Methodological, 37(8):747⁻768, 2003.

R. M. Russell and L. J. Krajewski. Coordinated replenishments from a common supplier. Decision Sciences, 23(3):610⁻632, 1992.

A study of flow management policies with advance demand information

Mohamed Zied Babai, Yves Dallery

Nowadays, the efficient management of supply chain flows is a very important issue for most companies to be taken into consideration. Cost reductions and higher customer service levels stemming from a better control of inventory can be substantial. Using advance information on future demand may help to achieve these objectives. In this work, we provide a classification of flow management policies based on the type of demand information. Two approaches are distinguished, namely : the future requirements based approach and the inventory consumption based approach. The first approach is used in presence of Advance Demand Information in the form of firm orders or forecasts, and the second one is used when no demand information is available.

We focus on future requirements based policies. In particular, we investigate a pure single-stage and single-item inventory system with Advance Demand Information. We propose a new forecast based flow management approach in which the Advance Demand Information is given by forecasts and forecast uncertainties. In our approach, we are not interested in the forecasting techniques but we suppose that forecasts are an exogenous data given at the beginning of the horizon. In fact, we are interested in the computation of the forecast uncertainties. Using this demand structure, two forecast based inventory management policies are proposed, namely : the (r_k, Q) which is a dynamic reorder point policy and the (T, S_k) which is a dynamic order-up-to policy. These policies are extensions of the standard (r, Q) and (T, S) policies.

The parameters of the forecast based inventory management policies are studied and compared to those of standard policies. We introduce a new safety parameter called safety quantity which can be considered as a dynamic safety stock, and we study the impact of the forecast uncertainty model on this parameter. We also investigate the benefits of using the advance demand information in the inventory system. For this purpose, the average inventory level computed by using the forecast based policies is compared with the one given by using the standard policies. This analysis enables us to identify conditions under which the use of forecasts may bring significant benefits. Furthermore, the equivalences between the materials requirements planning (MRP) policy and the proposed forecast based policies are studied. We show that the (r_k, Q) and (T, S_k) policies are respectively equivalent to an MRP policy using fixed order quantity and periodic order quantity as lot-sizing methods.

Linear & nonlinear work-in-process (WIP) clearing in supply chain operations planning (SCOP) with planned lead times

Baris Selcuk, Jan C. Fransoo, A.G. de Kok

Setting the correct parameters (especially planned lead times) has been a major concern for supply chain operations planning because of its effect on the timing and sizing of production and replenishment decisions. In this paper, we develop an adaptive mechanism that updates planned lead times responsive to the changes in demand forecasts and WIP levels. We employ planned lead times in controlling release decisions and identify "lead time capacity" using clearing functions to model the WIP throughput dynamics. We suggest the clearing function should be based on the short-term probabilistic behaviour, and compare it with the other representations in the literature. A simulation model of a single-item producer-distributor supply chain situation is used as the experimental test-bed. We provide the relative performances of adaptive strategy to the fixed strategy under different scenarios, and we also provide insights on the appropriate representation of clearing functions.

Experimenting with different supply chain parameters using Colored Petri Net simulator

Dragana Makajic-Nikolic, Mirko Vujosevic

The paper presents some of the results obtained by studying Petri Nets' capability for modelling and analysis of Supply Chain (SC) performances. We have developed a simulation model using a timed, hierarchical Colored Petri Net (CPN) and software package CPN Tools. This CPN simulator is one version of the well-known Beer Game and overcomes some shortcomings we have observed playing other electronic Beer Games. For instance, unlike many other Beer Game implementations, where one participant must be engaged for each stage, here one participant may simultaneously experiment with the strategies of all SC stages. Also, here player can define in advance the rules of demand forecasting and inventory control policy and analyze their consequences. To analyze simulation reports, we use macros in MS Excel. We have modelled a simple four-stage supply chain with one player at each stage - a retailer, wholesaler, distributor and manufacturer and production and distribution of one article - beer. The two main processes of each participant, which we have observed, are: delivery of purchased products and forming one's orders according to new orders, i.e., CPN simulator only follow up on orders and deliveries in time.

We have modelled the described SC with timed hierarchical Colored Petri Nets. The net structure consists of four hierarchical levels. The top level of the model is the whole supply chain: a customer and the four mentioned phases. The four phases (participants), a retailer, wholesaler, distributor and manufacturer are presented by means of sub-pages. At the next hierarchical level every subpage (SC participant) has one sub-page which models strategy choice, which, then, have sub-pages for modelling three demand forecasting methods: last period demand (LPD), weighted moving average (MAV) and exponential smoothing (EXP).

Our CPN simulator allows easy experimenting with four different parameters:

- Demand forecasting methods. Each player can choose one of three predefined and modelled demand-forecasting methods: LPD, MAV, and EXP, and define their parameters and

weights. Trend of orders is calculated using those methods.

- Inventory control policy. At the moment of receiving the order it has to be checked if the inventory stores the needed products and decide about delivery of purchased products. Our CPN simulator allows defining of different delivery function. It also allows defining of different behaviour CS participants in forming one's orders according to new orders, calculated trend and the needed level of inventory.
- Customer's demands. It is possible to simulate different customer's demands in time.
- The times needed for creating personal orders, the production and delivery procedures. Those times can be deterministic or stochastic.

According to the simulations results we can measure different performances whose changes are the consequences of player's decisions: reactions of participants to sudden changes in customer demands (the bullwhip effect), changes in inventory in a time, surplus of inventory goods, changes in inventory costs and backorder costs in a time, inventory level at the end of simulated period, total costs of each SC participants and of the entire SC.

Computer-aided modeling of supply chains in a hierarchical decision making process

Michael Kämpf

This paper presents a framework for handling the process of modeling, simulation and optimisation of supply chains with an arbitrary structure. Since in the last years the power of computers growed up very quickly, computer programs have the chance to handle more complicated supply chains than before. That means on the one hand that you can model, calculate, simulate, and optimise supply chains with multiple items and on the other hand it becomes possible to form the whole supply chain from the producer over the different intermediate stores with their delivery chains until the ultimate consumer. To handle such an amount of data you need a good visualisation tool for modeling supply chains in an easy way. Furthermore, we often want to optimise such a modeled supply chain. While analytical solutions for complex supply chains with multiple items currently becomes insolvable looking for applicable heuristical solution strategies is required.

Using a hierarchical approach with two decision levels we have developed a simulation model for an arbitrary multi-echelon supply chain with multiple items. On the first level of the decision making process the acceptance of an arrived client order is made. Accepted item requests can enforce production order. These requests are collected in a pool of production orders. The second level figures out which item request from the pool to handle next by which producer.

To optimise such complex supply chains we apply simulation optimisation. In this case it is a feedback process between a heuristic optimiser and a special developed supply chain simulator. Since the computational power for most supply chain problems using the technique of simulation is very high, we distribute the optimisation process to different computers connected through a communication network (parallel optimisation algorithm).

The focus is to find good methods for modeling arbitrary supply chains, simulate them and optimise some special problem oriented parameter. To handle this, a noncommercial software tool was developed, which is easy in use through a graphical interface for modeling, simple to advance through modern programming concepts and leads to fast optimisation results while different optimisation strategies are implemented. Each discrete model offers the same internal

structure including descriptions of static and dynamic model elements, optimisation variables, assessed, and nonassessed output values. Through that construction the modeler is limited to make mistakes while creating the structural model. Furthermore, it becomes possible to model any existing supply chain without restriction to complexity and mathematical solution algorithms. No special formed data are required. To influecne the optimisation process it is possible to choose one of the implemented heuristical optimisation algorithms, e.g., (Parallel) Genetic Algorithms, Tabu Search, or Simulated Annealing. After the simulation or more generally the calculation took place, the output results will be assessed and used to control the optimisation process. The interaction of different model elements, e.g., a calculator and an optimiser, is shown by an example of a supply chain.

Incentives and information asymmetry in inventory control

Charles Corbett

This tutorial will provide a selective overview of how incentives and information asymmetry affect inventory decisions. The OM literature on these issues has exploded in recent years; this tutorial will focus on two early models in this area. The first will look at a basic model of asymmetric information about agent type, in the setting of a two-level (r,Q) inventory system, and discuss how the economics literature on adverse selection allows one to derive optimal contracts to deal with that asymmetric information. The second will look at a basic model of asymmetric information about agent effort, in the setting of a two-level supply chain where both parties exert effort that is unobservable to the other party, and discusses how the economics literature on (double) moral hazard allows one to derive optimal contracts to deal with this hidden effort. In both cases, we will also discuss limitations of these models, and recent and ongoing work to address those limitations.

A framework for collaboration in a supply network

Kobe Naesens, Ludo Gelders, Liliane Pintelon

Nowadays, companies operate globally and face constantly increasing competition. To remain competitive, short term planning cannot eclipse long-term strategy. Achieving a competitive advantage will become in the future more important due to shorter product life cycles, shrinking profit margins, increased delivery requirements, etc. Therefore, market leaders will extend their lead while others fall behind and ultimately disappear.

To maintain a competitive advantage, working together or collaborating with other companies could be a critical success factor. In operations management for example, a collaboration strategy instead of a strict competitive attitude will change management focus from inventory control to information flow control and could therefore eliminate at least part of the bullwhip effect.

Extensive academic research addressed the collaboration inside the supply chain (vertical collaboration). Almost every scholarly business journal published some optimisation models. Despite the persuasive research, the literature survey indicates some major theoretical shortcomings. The main problem is neglecting collaboration between supply chains (horizontal

collaboration), which in part accounts for the reluctance of the industry to implement collaboration in a network (both horizontal and vertical collaboration). These shortcomings are firstly presented in this paper.

One of the major shortcomings is the lack of an appropriate strategic decision support framework for the implementation of horizontal collaboration in a supply network. Therefore, this research focuses on a framework for inventory-pooling between different supply chains. The first step is generating an appropriate classification to subdivide collaboration. Many classification methods have been suggested in literature. In this research, three appropriate categorisations are developed further and integrated: according to the different levels, the forms of collaboration and the models of leadership. The classification is analysed along two criteria: "complexity" and "criticality". The complexity determines how easily a partner may be exchanged by another (partner-potential) and can be measured by the 5-forces model of Porter. The criticality indicates if the activity is part of the priority-activities of the company. Based upon this classification, we define "true collaboration". True collaboration requires at least formal cooperation but does not include mergers and acquisitions. Applying this definition of true collaboration leads to the necessity of at least a moderate criticality and complexity before true collaboration in inventory-pooling can succeed. This classification is described in detail in the paper.

Supply chain contracting under mild behavioral assumptions

Mirko Kremer, Diedrich Bremer, Stefan Minner

We address bounded rationality in the context of decentral decision making. This is an issue widely disregarded in the recent model-based research on "optimal" coordination of decentralized supply chains. We provide two motivations for including bounded rationality into supply chain coordination models, review the related literature, support the potential of this research direction by a formal model analysis, and discuss promising paths for future research effort in this field.

In our model analysis we consider a simple supply chain with a manufacturer selling to a newsvendor-type retailer. We extend the standard setting and explore how supply chain contracting is affected by a relaxation of the strong rationality assumption commonly used in the models. Specifically, we consider a retailer with an ordering behavior that deviates from mere expected profit maximization and is rather consistent with regret and disappointment theory. We explore and compare the impact of such behavior for two classes of supply chain contracts: those which are coordinating in the standard setting as well as the wholesale price only contract which is generally deemed to be non-coordinating.

The impact of dynamic pricing on economic ordering decisions

Sandra Transchel, Stefan Minner

This paper analyzes the impact of dynamic pricing on the economic order decision of a monopolist retailer. Products are procured from an external supplier according to the economic order quantity (EOQ) model and are sold to customers on a single market without competition following the simple monopolist pricing problem. The coordinated decision making of optimal

pricing and optimal ordering is influenced by operating costs - including ordering, purchase, and inventory holding costs - and the demand rate obtained from a price response function. The retailer is allowed to vary the selling price, either in a fixed number of discrete points in time or continuously. The paper illustrates the benefit of dynamically changing prices in a pure EOQ environment and provides structural properties of the optimal time instants when the price has to be changed. Taking into account costs for changes in price, it provides numerical guidance when and how often price changes are beneficial during the order cycle.

Inventory problems with perishable items; fixed lifetimes and backlogging

Patrik Tydesjö, Fredrik Olsson

Our model deals with a single product and a single stock location where demand is generated by a stationary Poisson process. The replenishment leadtime from the external supplier is fixed. The lifetime T of the item is also fixed, and aging is assumed to begin when the order is placed. When the age of a unit has reached T the unit is useless and thus discarded from the system. The replenishment policy is assumed to be an S-policy. In this specific case this means that when a unit perishes or a customer arrives a new unit is immediately ordered from the supplier. Demand that cannot be met immediately is backordered.

One of the main problems when handling a model like ours is that the superpositioned process, which arises from both customer demand and perishing, is not a Poisson process. We however show how the results from a paper by Schmidt and Nahmias from 1985 can be used to solve our model exactly. Their model differs from ours in that they assume lost sales instead of backlogging. The lost sales assumption implies that there will always be exactly S units in the system. Schmidt and Nahmias then derive some partial differential equations that must be fulfilled and then solve these to obtain the steady-state distribution of the age of the S units.

The following observation is crucial. In the non-zero leadtime, backorder case, the joint steady state distribution of the age of the S units not yet assigned to a customer is the same as for the S units in the zero leadtime, lost sales case. Recall that in an S-policy system with backlogging there are always S units that are not yet assigned for customers. A zero leadtime in the lost sales case means that no demand will be lost. This shows that we can use the Schmidt and Nahmias results to calculate the distribution of the S youngest units in the system.

Our results are then compared to the results in a paper from 1995 by Chiu. The difference between our model and Chiu's is that Chiu assumes an (R, Q)-policy. The two systems are identical if $R = S - 1$ and $Q = 1$. We compare the two models in this particular case, and we find that our models performs better. The benefits of the Chiu model are more accurate when Q is a bit larger.

The conclusion is that by a simple observation one can use the results from the Schmidt and Nahmias lost sales model also in the backlogging case to obtain an exact result.

Revenue management and operations - integrating pricing and inventory control

Moritz Fleischmann

Pricing decisions are receiving growing attention in supply chain management, both in academia and in business practice. In particular, many have highlighted the potential of dynamic pricing as a means to increasing revenues, inspired by the widely publicized example of the airline industry. At the same time, price swings may pose serious challenges for operations management. The systematic integration of pricing and operations decisions, and thus of revenue maximization and cost minimization into profit maximization, is yet in an emerging stage.

This tutorial is intended to highlight emerging research on joint pricing and inventory optimization. We will present basic principles of revenue management and discuss their implications for operations management. We will then distinguish different streams of literature, which we address in more detail. These include markdown pricing, inventory transfer, and promotion optimization. For each stream, we will discuss typical modeling approaches, key results, and open challenges.

Inventory inaccuracy in the retail supply chain: coordination versus auto-ID technology

Yacine Rekik, Zied Jemai, Evren Sahin, Yves Dallery

This paper studies a supply chain model in which a single manufacturer sells a single product to a single retailer who faces the Newsvendor problem. One of the underlying assumptions in the formulation of the Newsvendor problem is that there are no anomalies in the expected physical and informational flows and, as a consequence, the retailer operates with accurate inventory records. In real practices, due to defects arising at different points, this assumption may not be verified resulting in poor product availability.

This paper proposes a comparison between three ways of "approaches", an inventory system of a retailer with internal errors resulting in inventory inaccuracy can be managed: in the first approach, the retailer is unaware of errors in the store. In the second approach, we focus on the benefits achieved through a better knowledge of internal errors and through taking them into account when formulating and optimizing the inventory system. Our main contribution concerning the second approach is to propose an analytical way to model and formulate the error issue. In the third approach, we focus the contribution of auto-ID technology in such a retailing situation.

In the analysis of the centralized system, we show that the retailer has much to gain not only from deploying auto-ID technology but also from identifying ways to improve the existing operational processes such as optimizing the system in presence of inventory inaccuracy. To contribute to a better understanding of the impact of the introduction of the auto-ID technology on supply chain partners, an analysis of the decentralized supply chain under a price-only contract is provided. In this analysis, we focus on the cost of auto-ID technology and determine conditions in which the implementation of the technology is economically feasible for both the manufacturer and the retailer.

The main questions that this paper addresses are: 1. How can we analytically model the

error issue in a Newsvendor framework? 2. What is the impact of auto-ID technology on the decentralized supply chain? 3. Which technology price make auto-ID feasible and how should this price be shared among the supply chain partners?

Raw materials procurement with commodity options - a risk management approach

Jan Arnold, Stefan Minner

Risk management has received increasing attention in connection with operations and supply chain management issues. Option pricing has developed to an important instrument in the financial community but its meanings are rarely analyzed in procurement models. This paper extends an existing risk management approach of Ritchken and Tapiero (1986) which uses negotiated commodity options for hedging against price and demand uncertainty.

In particular, we use exogeneous commodity option prices derived from financial theory to optimize the procurement policy of a purchasing agent. We extend the model of Ritchken and Tapiero by taking into consideration short-selling, upper and lower bounds for the decision variables, and a budget constraint. Conditions for optimal purchasing policies as functions of means and variances of the commodity price result from a non-linear, convex optimization model.

Optimal size, location, and inventory decisions in an infinite-horizon newsvendor-type environment

Hussein Naseraldin, Yale T. Herer

In this paper, we research the management approach that quantitatively combines strategic and operational decisions. This approach, integrating decisions from various horizons, is new (only a handful of articles have even considered related problems) but it is increasingly attracting attention due to the potential benefits it offers. The environment that we examine can be depicted as a multiple-newsvendor infinite-horizon environment. Managing such a system entails different decisions on different horizons. Decisions such as the number and location of retail outlets are part of the strategic design of a supply chain. Inventory control decisions, on the other hand, are considered to belong to the operational side of a supply chain. Lateral transshipments is an inventory recourse, which has been emerging as a beneficial recourse, which builds on recent developments in information technology. It is based on stock movement whenever one location or more faces excess and others face shortages. This practice mitigates the impact of the stochasticity in demand that the system faces.

Integrating these decisions, strategic and operational decisions, has the potential to improve system performance. We proceed gradually until the synergy of operational and strategic decision making is patently visible. First, we start with a system, without lateral transshipments, which contains two echelons: customers and retail outlets. We designate retail outlets as the entity that serves the end-customers at the lowest echelon. This entity satisfies the demand arising from customers dispersed over a given region. We present a formulation of this case; we analyze the system and optimally solve it. We utilize this system as a foundation for analyzing the general case of multiple retail outlets. The proposed model integrates the above-mentioned

decisions and simultaneously derives the optimal solution. We analyzed the system from an expected cost point of view, considering fixed, inventory, and delivery costs. We showed that the system optimally operates when retail outlets are evenly spaced and that the system's expected cost function is a quasi-convex function in the number of retail outlets. We augmented our methodology by examining the advantage of the simultaneous approach over a sequential one, which results in a larger number of retail outlets in the solution space and a larger objective value in the objective space. Next, we analyze the system under the practice of lateral transshipments. We proceed gradually by analyzing a system of two retail outlets and examine the effects that lateral transshipments has on the system both on the solution and objective function spaces. Managerial and model insights are discussed.

Optimal asymmetric policies for inventory systems with lateral transshipments

Fredrik Olsson

Using lateral transshipments can be beneficial in order to improve service levels and to reduce system costs. This paper deals with a single-echelon inventory system with two identical locations. Demands are generated by stationary and independent Poisson processes. In general, if a demand occurs at a location and there is no stock on hand, the demand is assumed to be backordered or lost. However, in this paper, lateral transshipments are possible.

First, we assume that the locations are identical and apply continuous review (R, Q)-policies. If a transshipment is realized, the sending location triggers a replenishment order from the supplier if the inventory position, IP (stock on hand + outstanding orders), has dropped to R. If it is not possible to make a transshipment, the demand is assumed to be lost. We shall distinguish two cases. In the first case it is assumed that each item in the ordered batch will arrive after different exponentially distributed times. In the second case we assume that when a batch of size Q is ordered, the whole batch arrives at the same instant of time after an exponentially distributed time (with intensity γ_i for each batch ordered at location i). With Markov theory we are able to show that the optimal $R = -1$ in a number of cases. Stated another way, if $R = -1$, the inventory position will never reach the reorder point, and the location will consequently never replenish stock from the supplier. Instead, the location only replenishes through lateral transshipments from the other location which turns into a dominant location, the master location. Thus we show that the optimal policy may be asymmetric even though the problem is symmetric.

Second, we relax the assumption of (R, Q)-policies and derive the optimal replenishment policy using stochastic dynamic programming. The dynamic programming problem is stated as a semi-Markov decision problem, where each item outstanding at location $K \in \{1, 2\}$ arrives after a leadtime L_k which follows an exponential distribution with parameter γ_k.

When we applied a (R, Q)-policy, only one location could order at any decision epoch. Furthermore, when applying an (R, Q)-policy, a location can only order when there is a decrease in the inventory position. This meant that, it was not allowed to order when; 1) an outstanding order arrived in inventory, 2) a customer arrived and there was no stock on hand at either location. In order to find the optimal replenishment policy we relax these assumptions, and allow the locations to order at any decision epoch.

In our numerical study we find that a (R, Q)-policy may be a reasonable choice of replenishment policy when the demand rate is relatively low.

Optimization of multi-echelon multi-item inventory systems

A.G. de Kok

In this presentation we discuss multi-echelon multi-item models under stochastic demand and stochastic lead times. Based on fundamental results for the optimal control policies for divergent multi-echelon systems, we conjecture a set of necessary conditions for optimal control of multi-echelon multi-item inventory systems under various control policies. These necessary conditions can be interpreted as cost balance equations. These equations provide insight into the optimal positioning of safety stocks in a system. We discuss results for both echelon stock control policies and installation stock control policies. We also discuss interesting open problems to be solved to make further steps in the development of optimization methods for real life problems.

Service parts supply systems and maintenance logistics

Alejandro Parodi, Liliane Pintelon, Ludo Gelders

Until now, service parts supply chain management and maintenance logistics are two fields commonly considered separately. The high pressure set on technical system availability and the stringent profit margins imply lean and effective operation strategies that cross company's borders. As a consequence, the requirements of maintenance logistics and service parts supply chains are more demanding. Taking advantage of the current possibilities in the supply chain opens new opportunities for the service/spare parts logistics management.

In recent years, the concept of inter-company collaboration within the supply chain has received significant attention, which is witnessed both in practice and in academic research. This phenomenon of working together inside the supply chain is defined as vertical collaboration. Despite of the widely accepted benefits of vertical collaboration in the supply chain, little importance has been given to explore its potential on inventory control in service parts supply chain. Attention is still mainly focused on manufacturing and retailing chains.

Service Parts Supply Chains, characterized by handling thousands to hundreds of thousands different items with complex control characteristics in multi-echelon, present a real challenge to logistics practitioners and researchers. Including collaboration between the service parts suppliers and clients does not make it any simpler.

In the past few decades many models dealing with stock allocation and supply of service parts have been developed to represent these multi-echelon systems managed by diverse control characteristics. The METRIC model developed by Sherbrooke (1968) and its extensions are just some of these important contributions. However, almost all attempts, if not all, remain limited to modelling situations that involve only one actor controlling the network. Clients are just passive actors (an installed capacity) signalling a stochastic demand for service parts.

In reality these service systems involve at least two actors: the supplier(s) (OEM, parts broker, service provider, etc) and the client (private or business). The installed capacity at business clients is maintained by a mix of preventive and corrective maintenance policies (the maintenance concept). These maintenance actions add timely information to the maintenance logistics problem triggering different inventory control methods. If maintenance of the installed capacity is not under the supplier's control, the conflicting interests of clients and

service providers are emphasised. As a consequence, suppliers and industrial clients separately optimise their "service parts" and "spare parts" respectively, leading to inappropriate inventory levels. As John A. Muckstadt stated: "local optimisation leads to global disharmony".

The required shift in mind cannot be achieved until a reasonable vertical collaboration occurs and adequate control characteristics are implemented in the supply and demand network of non-manufacturing (service and spare) parts. The requirements of user-supplier interfaces should be considered concurrently. This paper identifies the potential benefits of jointly controlling non-manufacturing parts inventory between the service parts supply chain and the maintenance logistics. Six elements are included to describe the coordination and control scenarios: (1) supply chain capabilities, (2) business context, (3) operations intensity, (4) part life cycle, (5) maintenance control and (6) maintenance concept.

Lot-sizing for inventory systems with multi-level item remanufacturing

Ivan Ferretti, Simone Zanoni

Due to environmental and legislative reasons, the importance of reverse logistics is increasing. In the recent years many papers were presented about reverse logistics systems with manufacturing and remanufacturing options, i.e., hybrid inventory systems with manufacturing and remanufacturing options. In particular, this system is composed of two different stock points: a serviceable containing final products ready for selling, and a second one, named recoverable, which receives items coming back after the customer utilization.

We face a closed loop supply chain seen as an extension of the reverse logistics system, where we jointly consider the assembly and disassembly operation processes, with a multi-level inventory system. We take into account a disposal option in order to consider also the possibility of failure in the recovery operation at the disassembly process.

A simple version of such a system has been studied by Teunter (2001) where two different inventory evaluation methods are compared in a disassembly system with remanufacturing.

In a recent study Tang et al. (2004) developed a model based on MRP theory supporting decision making in disassembly strategy: they propose a decision tree approach for the economic quantification of the returned products and recoverable items, thus estimating the inventory holding costs.

We study inventory sytems with disassembly processes in remanufacturing systems with the focus on evaluating their economic consequences. Recovered items are as good as new and can satisfy the same demands like new items. The model developed assists decisions such as to which degree and for the sake of which components should the returned items be disassembled. Consequently, using economic values of recoverable items, we obtain the inventory holding cost of these items. This information is further used for determining an inventory control policy.

We derive simple formulae for determining the optimal lot-size for the disassembly returned items remanufacturing or production/procurement of new components.

In the future research we try to validate the analytic model developing a simulative model. Moreover we try to extend the deterministic model proposed to the stochastic case.

References:

1. Tang O., Grubbström R.W., Zanoni S. (2004) "Economic Evaluation of Disassembly Processes in Remanufacturing Systems", International Journal of Production Research, Vol.

42, No. 1, pp 3603-3617.

2. Teunter, R. H. (2001) "A Reverse Logistics Valuation Method for Inventory Control", International Journal of Production Research, Vol. 39, No. 9, pp 2023-2035.

Optimal ordering decision using returns information: the value of quantity information

Umut Corbacioglu, E.A. van der Laan

Supply chain structures were traditionally perceived linear structures; starting from supplier down to fulfillment of customer passing through manufacturing, distribution and retailing. This one way flow of goods and information turned out to be insufficient (or over-simplistic at least), leading to recognition of Reverse Logistics in the last decade from practitioners and academics. The term reverse logistics encompasses the flow of items opposite to the traditional supply chain flows and related information about such flows.

According to Souza et al. (2003), much of the recent literature has an emphasis on end-of-use (or end-of-life) returns with focus on issues of inventory control, scheduling and materials planning. Similarly, Tibben-Lembke and Rogers (2002) argue that collection and disposition of returned product in the retail context have been largely ignored, although much has been written about many specific aspects of reverse logistics.

Although remote purchasing was in the scene for a long time in the form of catalog and telephone sales, using the web as a sales channel brought about an increase in the volume of sales, and consequently returns. Estimates for returns faced by e-tailers range from 10 % to 50 % in various sources.

In the current e-commerce practice, most of the time customers are required to get authorization from a web page or a call-center for returning an item. The information provided by the customer at the authorization stage constitutes a new aspect that is not considered in the literature. But, this information is collected by incurring information system costs or call-center costs. Besides, it adds to the hassle of returning an item faced by the customer. Some experts argue that, the hassle of returning an item, added to the risks of making a remote purchase, is one of the main effects limiting the growth of e-commerce. Therefore, with the hidden effect on customer behavior, one may question the usefulness of collecting such information.

In this paper, we develop newsvendor type models to inquire the issue of value of quantity information in reverse logistics/consumer returns context. First, we approach the problem as a so-called random yield model (see Anupindi and Akella (1993), Parlar and Wang (1993)) with two supply modes; an external perfectly reliable supplier and the returns channel seen as an unreliable supply source with random yield. "Reliability" in this context pertains to "re-salability" of the returned item. Using this model we identify regions where returns the channel is used or an order is placed only from the outside supplier.

Next, building on this model, we analyze a similar model where the number of available returns is known, but still yield uncertainty remains. This quantity does not reflect the actual number of returns in the return pipeline, the interpretation is that it is the number of items that the company is sure to receive.

References:
1. Souza G., Guide V.D.R., van Wassenhove L., Blackburn J.,(2003) Time Value of Commercial Product Returns. INSEAD Working Paper 2003/48/TM.
2. Tibben-Lembke R.S., Rogers D.S. (2002). Differences Between Forward and Reverse Logistics in Retail Environment, Supply Chain Management 7 (5) 271-282.
3. Anupindi R., Akella R., (1993). Diversification Under Supply Uncertainty, Management Science 39 (8), 944-963.
4. Parlar M., Wang D., (1993). Diversification Under Yield Randomness in Inventory Models, European Journal of Operational Research, 66, 52-64.

Inventory models in the mobile business environment

Irena Okhrin, Knut Richter

In this paper we investigate the impact of the deployment of wireless technologies on the development of business processes in a company. Especially, we explore how mobile solutions affect the inventory decisions of a producer and develop mathematical models for inventory management problems in the mobile business environment.

We consider a company that manufactures some product and customizes it according to the individual wishes of its customers. To better understand the needs of the clients, we find out the exact characteristics and configuration of the demanded goods, as well as consult and help the customers, the supplier's consultant visits each client and makes the final agreement with him. The company cannot start the production of goods for a client before the agent attends him and achieves the agreement with him. Thus, the sequence of visiting clients is essential and has big influence on production and inventory management costs.

We assume that the consultant possesses a mobile device that is capable to connect to the enterprise resource planning system and upload or download data. After discussing with the client all details the agent enters the modified or newly obtained data to the corporate database. Only after all these values have been saved in the enterprise resource planning system the supplier can start production process. In contrast, if wireless technologies were not available, then the consultant at first has to visit all clients and only afterwards he can return to this office and input all new data into the corporate databank. This leads to essentially longer order processing times, reduces service quality and decreases customer satisfaction.

We model the logistics processes in the described settings in two stages - planning and operational. The aim of the supplier in the planning stage is based on the known demand data and capacity constrains determine such an order of attending clients that minimizes production and inventory management costs. On the other hand, at the operational stage the supplier wants to reschedule the production plan to effectively react to the changes in customers' demand.

We decomposed the planning model into the interconnected master problem and subproblem. The master problem summarizes the mobility of the agent and the information flows between the agent and headquarter while the sub-problem encompasses material flows and has a form of a dynamic lot sizing problem. For the incapacitated case of our model we have shown that if the supplier does not face the capacity constraints then the visiting sequence will coincide with the client numbers. Moreover, for the general case we proposed the rules to find an initial feasible solution for the order of attending clients. Besides, we proved several important

properties for unrestricted, bounded and capacitated versions of the sub-problem and adapted the well-known dynamic programming algorithm to solve them exactly.

Economic effects of mobile technologies in pre-sell distribution

Grigori Pichtchoulov, Knut Richter

Distribution of goods is realized in many industries by means of representatives who travel through assigned territories, promote the products and services to customers and execute sales operations, while the goods sold by the representatives are normally being delivered to the customers later on. With that the efficiency of representatives' operations determines to a great degree the efficiency of a company in distributing its goods. Due to many practical reasons - like, for example, a large number of customers and/or their geographical dispersion - the distributing company may have to assign different territories to several different representatives, which then carry their work independently of each other.

Thus, an efficient allocation of goods to the representatives who have to efficiently distribute these goods among the customers may become an important issue under uncertainty of customer demands, and we focus in this paper on potential improvements which mobile technologies might deliver there, being introduced into the company's decision making. Namely, enabling a centralised and real-time coordination of the representatives' operations, the mobile facilities may enable a better distribution of goods between the company's customers. To capture such potential improvements we consider a company which delivers a particular product to a number of predetermined customers, and model its distribution operations in the following two different environments: first, without any presence of mobile facilities in the company's decision making, and, in the second case, making use of them. To see what consequences it will have for attaining the company's goals becomes our task.

We apply stochastic programming methodology to model the agents' multistage decision making in both environments. The stochastic programming model arising in the mobile environment is shown to relax the constraints of the corresponding model in the non-mobile case and, hence, to deliver a generally better representatives' performance in terms of average product availability and customer satisfaction. To quantify this performance improvement, we provide an efficient computational algorithm to compute the expected system-wide performance under optimal decision making as a function of the company's inventory level, in both environments - with and without mobile technologies, for any configuration of a distribution system, while assuming the customer demands to be independent random variables with discrete finite distributions. The computational procedure implements an explicit backwards evaluation of the expected recourse function. Some computational results for selected configurations and demand distributions are presented, showing improvements in product availability when centralized and real-time resource allocation is carried out by means of mobile facilities. Although being discussed in a deliver-to-order context, the presented approach is shown to stay valid for any demand-driven system like assemble-to-order, as long as the company's mobile representatives have to efficiently share its limited resources - capacities and/or inventory - while making their decisions.

Innovation of supply chains in computer-manufacturing industry

Ondrej Myslivecek

During last few years the situation on market of computers, notebooks and servers has rapidly changed. It was caused by entry of new firms to these branches that at first focused their pursuit mainly at low-cost segment of notebook's market. As they improved their position at this segment they are attacking hi-tech segment more and more with strategy of powerful notebooks with relatively low prices. That's why well-established computer-makers such as IBM, Dell, HP and others are forced to lower their prices to stay competitive. Consequently these firms have to cut their cost to the lowest level possible. The solution to this is to create and maintain effective supply chains of not only inventory. Because these renowned manufacturers outsource the manufacturing as a whole, there is only tiny space to lower costs at this company processes. The latest trend is to outsource the whole process of designing new products, manufacturing and shipping them to customers. The original manufacturers have transformed to selling organizations and their employees almost never see the products they care about. It greatly simplifies IT infrastructure that can be freed of logistic of sub-products and other inventory as well as other processes that refers to design, manufacturing and shipping. On the other hand as the amount of inventory's exchange decreases the amount of information exchange between former manufacturer and the real manufacturer rapidly increases thus creating another network of supply chains necessary for various members of such network to work effectively. Information about orders, time of delivery, repair under guarantee and other repairs (quality management), customers' experiences and complaints. And this is only tip of the iceberg.

So the simplification of the processes in manufacturing and shipping brings necessity of more complex systems for storing information and sharing them among involved subjects. From this point of view it seems that the change in complicacy is arguable and it only means problems with restructuring. What are the benefits that make the companies to do so? It allows all companies to do those things they are best in. In future the computer-manufacturers should outsource almost all processes except those that will bring company competitive advantage (marketing, research and development) or those the company can manage by itself in a better way. The company's efforts should change from creating great computers (notebooks, servers etc) to meet the needs of consumers. They don't need exactly notebook, they need to carry their data with them, work when traveling, enjoy themselves when traveling etc. This trend should result in a complex system of highly specialized companies that will intensively communicate with each other to ensure effective cooperation leading to perfect satisfaction of consumer (inexpensive products of good quality, fast delivery etc). And the customers' satisfaction is the right means for company's growth.

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