# 17<sup>th</sup> International Symposium on Inventories

August 20-24, 2012 ... InterContinental Budapest, Hungary

# Session chairs' report

# AUGUST 20, 2012 Opening Plenary Session

by Stefan Minner



Louis Maccini from Johns Hopkins University, USA presented the manuscript "Inventory behavior with permanent sales shocks" coauthored by Bartholomew Moore and Huntley Schaller.

This paper contributed by the Economics Section of the ISIR-society provides a different perspective on sales and long-run production variability than is usually discussed under the phenomenon of the bullwhip-effect. Three perspectives from a theoretical and empirical analyzed, production perspective were smoothing, stockout avoidance, and cost shocks. Louis Maccini gave the audience three traditional inventory puzzles and discussed answers from the new approach to estimate, test, and calibrate inventory models from an economics perspective.



The second presentation on "The role of supply chain management initiatives in achieving competitive advantage" was given by Alan Stenger from The Pennsylvania

State University, USA. Starting with an introduction into corporate strategy and competitive advantage based on Michael Porter's work,



several successful supply chain cases from wellknown, world-wide operating companies were reviewed. These cases illustrate the success of cross-functional and cross-firm initiatives and the required change management processes.

The third presentation from the Forecasting section of ISIR on "Forecasting intermittent demand for inventory management" by *Ruud Teunter* from the University of



Groningen, The Netherlands gave an introduction into several forecasting techniques in service parts management, well known ones like the Croston's method, advancements like the Syntetos-Boylan-Approximation and more recent improvements and adjustments to these methods, especially to deal with the problem of obsolescence. A comparison based on real

world-data from a service company showed the advantages and disadvantages of the available forecasting techniques. Finally, Ruud Teunter advertised to further integrate forecasting and inventory management rather than using both methods separately and sequentially as suggested by many texts and research approaches in the field.

# Second Plenary Session

by Louis Maccini



Managing Energy Storages – Lessons from Inventory Theory & Research, by Stefan Minner of the TUM School of Management, Technische Universität München, Munich, Germany

The redirection of Energy Policy towards sustainability significantly

increases the share of renewably energies (e.g. 30% by the hear 2020 in Germany) but the complexity of matching demand with supply increases due to multiple sources and increasing uncertainty of supply. Increasing the efficiency of energy systems and to account for high fluctuations in energy supply and demand not only requires advances in generation and storage technologies but also in the management of the associated operations processes.

Energy storages are a core ingredient of a sustainable energy grid to decouple dynamic and uncertain, highly fluctuating supply of and demand for energy from different sources and at regionally dispersed locations. Where the majority of research is devoted to invent and improve storage technologies, efficiency increases might not only be achieved by enhanced technological capabilities but also by a more effective management of supply and demand.

Inventory theory offers a broad spectrum of models, approaches, and methods to manage reservoirs and storages where only few contributions were devoted to energy due to its limited storage ability. Minner presented a framework for advanced energy supply chain planning and management. Besides an overview on short- and long-horizon storage technologies and their characteristics, core ingredients were the modeling of demand, price and supply processes, especially the problem of intermittency of renewable solar and wind energy supply; multiple modes of stochastic and controllable supply; reservoir and storage capacity planning and multi-location coordination in smart grids; storage management policy structure and parameter determination methods; and decaying inventory and random yield due to storage and transmission.

DynamicDemandFulfillmentin SparePartsNetworkswithMultipleCustomerClasses,byHaroldTiemessenofIBMResearch,Zurich,Switzerland,Moritz



Fleischmann of the University of Mannheim, Mannheim, Germany, **Geert-Jan van Houtum** of the Eindhoven University of Technology, Eindhoven, The Netherlands, Eva Pratsini of the IBM Research, Zurich, Switzerland, and Jo Van Nunen of the Erasmus University, Rotterdam, The Netherlands

In his presentation van Houtum introduced a study of real-time demand fulfillment for networks consisting of multiple local warehouses, where spare parts of expensive technical systems are kept on stock for customers with different service contracts. Each service contract specifies a maximum response time in case of a failure and hourly penalty costs for contract violations. Part requests can be fulfilled from multiple local

warehouses via a regular delivery, or from an external source with ample capacity via an expensive emergency delivery. The objective is to minimize delivery cost and penalty cost by smartly allocating items from the available network stock to arriving part requests.

A dynamic allocation rule was proposed that belonged to the class of one-step lookahead policies. To approximate the optimal relative cost, an iterative calculation scheme was developed that estimated the expected total cost over an infinite time horizon, assuming that future demands were fulfilled according to a simple static allocation rule. In a series of numerical experiments, the dynamic allocation rule was compared with the optimal allocation rule, and a simple but widely used static allocation rule. It was shown that the dynamic allocation rule had a small optimality gap and that it achieved an average cost reduction of 7.9% compared to the static allocation rule on a large test bed containing problem instances of real-life size.



Durable Goods Production and Inventory Dynamics: An Application to the Automobile Industry by Adam

Copeland of the Federal Reserve Bank of New York, New York, U.S.A and **James A. Kahn** of Yeshiva University, New York, U.S.A.

Kahn introduced a model of the joint determination of production, inventories and

pricing of a monopolistically competitive durable good producer. The model gave rise to time varying markups that interacted with the inventory-sales ratio, even with flexible prices. Maximum likelihood estimation with automobile industry data yielded plausible parameter estimates and impulse responses. The model was then applied to analyze the impact of the "Cashfor-Clunkers" program, and found that the model predicted a negligible production response; essentially all the action is inventories. It lead the authors to consider evidence of threshold effects that implied a stronger response very far from the steady state. This resulted in a modest but more plausible production response to the policy-still modest was comparison to the sales impact, but now at least measurable. Even with some production response, the results still provided a cautionary tale for countercyclical policies that relied on stimulating consumer spending. Even an impact on spending need not translated into a comparable impact on employment and output.



Rommert Dekker receives the Fellow award

# **Economics of Inventories**

# AUGUST 20, 2012 > EC1

#### by David Bivin

There were two papers in this session and their approach to inventory analysis was substantially different. *Luca Benati's* paper, University of Bern "Sales, Inventories, and Interest Rates: A Century of Stylized Facts," (co-authored with Thomas Lubik) took a macroeconomic perspective while *Ram Ganeshan's* paper, "The Economics of Loyalty-Based Incentive Programs," (co-authored with Tonya Boone) examined inventory strategy at the firm level.

Benati and Lubik address the long-lasting puzzle of why inventories do not seem to fall when the real interest rate rises. Their methodology is innovative for several reasons. First they rely on national income account data extending back to the first quarter of 1919. Second, their estimates are generated using a Bayesian vector-auto-regression with time varying coefficients. With such a long span of time, it is not surprising that the authors would have a special concern with the possibility of structural change and these models have proven adept at identifying such changes. Third, the objects of interest for their analysis are the structural errors associated with the residuals of the estimation. The question is whether these shocks cause comovements in interest rates and sales that could confound the identification of an inverse inventory relationship with interest rates.

The authors identify structural change. Their conclusion is that the absence of a significant inverse relationship between inventories and interest rates is a post World War II phenomenon. Between World-War I and World War II, the relationship between inventories and interest rates was strongly negative. Moreover, while the correlation between inventories and interest rates was fairly stable prior to World War II, after World War II, the ratio has exhibited substantial instability. The paper is available at http://papers.ssrn.com/sol3/papers.cfm?abstract \_id=2055480

The paper by Ganeshan and Boone evaluates the benefits and costs of loyalty programs. Typically, for an annual fee, such programs offer their customers special benefits such as free shipping. The payoff function for the strategy is an interesting one. The firm profits from the membership revenue but once this revenue is received, it is not clear that the strategy is profitable for the remainder of the membership period. On the one hand, if membership generates additional orders, the firm receives the markup on those items. On the other hand, the firm must absorb the shipping costs on all of the orders placed by the member including those that would have been placed in the absence of the loyalty program. The relationship between the cost of the program and the total value of additional orders placed as a result of membership is crucial to the outcome. Ganeshan and Boone raise a very interesting and current strategy question and develop a comprehensive framework for addressing it.

### AUGUST 21, 2012 EC2

#### by Ram Ganeshan

This session saw three very interesting papers all dealing with inventories at the national level.

The first paper "**Production Chains, Demand, and Output Volatility in the Durables Sector: 1967-2011**" **David Bivin**, Indiana University Purdue University Indianapolis, USA addresses the decline of volatility of the US GDP starting in the 1980s in so called the "Great Moderation." Professor's Bivin's paper addresses if, in the Durables Sector, improvements in supply chain management – often attributed to the GDP stabilization – can be attributed to the change in demand for durables. The paper via a combination of estimation and simulation techniques finds that the volatility of output in the sector can be explained through changes in demand behavior (as less persistent shocks) controlling for innovations in production & inventory management.

Professor Attila Chikán, Corvinus University of Budapest, Hungary presented the second paper "Inventories in National Economies: A cross country analysis of macroeconomic data" - the paper was joint work with colleagues Kovács, Matyusz, and Sass. This paper is part of an ongoing book project on the behavior of national inventories (the Chair is eagerly waiting the release of this book!). The authors use the investment/GDP ratio as an indicator of macrolevel inventory information. They analyze over a 20-year time frame the behavior of inventories in developed countries. The interesting observation was that on different metrics, the behavior of inventories show "distinctive norms" and the takeaway was that understanding how monetary/fiscal policy or better management can impact these trends is of great value especially to emerging economies.

The final paper "The Role of Inventories in the Great Recession and Recovery" was presented by *Philippe de Rougemont*. In joint work with his colleague, Vincent Labhard, the presentation provided an expository view on the role of inventories in the 2008-09 recession and the ensuing recovery. How can a policy making institution use inventory movements at the country, regional, and global level to guide policy? The paper examines the role of an "inventory shock" following the Lehman Brothers collapse; the type and flow of inventories in the global supply chain, and how the inventory levels are inevitably linked to the financial conditions during the period.

Overall, the session was enjoyable and well attended.

#### AUGUST 23, 2012 > EC3

by James Kahn

# Felipe Schwartzman, Federal Reserve Bank of Richmond, USA "Time to Produce and Emerging Market Crises"

This paper is about the role of working capital in financial crises. The inventory/cost ratio is a measure of the time to produce and distribute goods ("time to produce") and, therefore, an important determinant of working capital demand. In the aftermath of emerging market crises, manufacturing industries with higher inventory/cost ratios experienced a larger drop in output, a drop which persisted multiple years into the recovery. This observation is shown to emerge following a persistent foreign interest rate shock in an environment where time to produce in different sectors matches inventory/cost ratios in the data. In such an environment, the interest rate shock is able to account for up to 25% of the deviation of output from its previous trend. The inventory/cost ratio is thus able to account for cross-sectional differences in the response to shocks. These results underscore first the importance of working capital constraints as a transmission channel for financial shocks, and second, the importance of persistent interest rate shocks as a driving force of business cycles in emerging economies.

Guido Voigt, Otto-von-Guericke University, Germany "Strategic Inventories and Supply Chain Behavior" (with R. Hartwig, K. Inderfurth, A. Sadrieh)

This paper reports the results of experimental evidence on strategic inventories in supply chains, based on a model by Anand, Anupindi, and Bassok ("Strategic Inventories in Vertical Contracts," *Management Science* **54** (10), 1792-1804). In the 2-period version of the model, a seller sets a wholesale price and a buyer chooses order size and sales in each period. The buyer's strategic choice of inventory in the first period induces a lower average wholesale price and improved supply chain performance, provided

holding costs are sufficiently low. The results of the experiment were that participants did hold strategic inventories in the low holding cost case, though below the levels predicted by the model. They quickly converged to (optimal) zero inventory holdings in the case of high holding costs.

RujingLiu,KoreaUniversity,SouthKorea"CoordinatedDynamicPricingandOrderingDecisions forPerishableProductswithMultipleDemandClasses"(withChulungLeeandEkPengChew)ExampleExampleExampleExample

This study considers a perishable product with a multiple period lifetime. Hence, in any period, the inventory contains products with different ages, purchased by different demand classes, which are independent to each other. The optimal order quantity for the new product (product of age 1) and the optimal prices for products of different ages are obtained. The advantages of dynamic pricing strategies include increased sales, lower product wastage, and higher profits.

# **Inventory Management**

#### AUGUST 20, 2012 ▶ IM 1

#### by Søren Glud Johansen

The session provided a nice demonstration of a truly international symposium. The three speakers came from countries (Hong Kong, Germany and USA) of different continents.

Frank Chen, City University of Hong Kong, Hong Kong and Quan Yuan "Analysis of supply contracts with a minimum quantity commitment and fixed order costs"

Frank Chen presented a model for a buyer who in a contract with a supplier has accepted to buy a minimum total (cumulative) order quantity over a planning horizon. The timing of each individual replenishment order, which incurs both fixed and variable costs, is up to the buyer. The speaker used a new state transformation method to show that the optimal policy is of a modified (s,S) form when the objective for the buyer is to minimize the total expected cost over the contract horizon. The new state transformation method can incorporate a contract where the total minimum order quantity is specified as the weighted sum of quantities of different products having the same fixed cost per replenishment order.



Karl Inderfurth and Josephine Clemens, Otto-von-Guericke University of Magdeburg, Germany "Supply chain coordination through risk sharing contracts under different forms of yield uncertainty"

Josephine Clements analyzed risk sharing contracts for a supply chain consisting of a buyer facing deterministic demand and a supplier who decides the production quantity. She considered two forms of yield uncertainty in a single period setting. The first deals with stochastically proportional yield where production output is a random fraction of the input quantity. The second sets the production quantity equal to the input quantity with a certain probability while the output is zero with the complementary probability. She demonstrated for each setting

that at least one of three investigated contracts can achieve coordination of the supply chain. The contracts under investigation are the simple wholesale price contract, a penalty contract and one that defines risk sharing in case of overproduction at the supplier.

#### Suresh P. Sethi, University of Texas at Dallas, USA, Tao Li and Jun Zhang "Supply diversification with responsive pricing"

For a firm facing an exogenously determined price and two independent supplies, it is known from the literature that cost is the order qualifier while reliability is the order winner. Suresh Sethi demonstrated that this result continues to hold when the suppliers' capacities are correlated and demand is price dependent. Then the firm orders only from one supplier if the effective purchase cost from him, which includes imputed cost of his unreliability, is lower than the wholesale price charged by his rival. Otherwise, the firm orders from both. The firm's diversification decision does not depend on the correlation between the random capacities of the two suppliers, but its order quantities do depend on the capacity correlation. With more than two supplies, the insight no longer holds.

#### AUGUST 21, 2012 ► IM 2

by Jacob Wijngaard

We had three interesting and smoothly presented papers.

The first paper "Buyer-supplier coordination for continuosly stocked items via retail pricing and revenue sharing" was by Avijit Banerjee, Ruo Du and Xiangrong Liu of Drexel University, USA. The paper considers a supply chain coordination problem with a single manufacturer and a single retailer but more products. The manufacturer produces the products batchwise and one by one. The market demand is price dependent. The retailer sets price and order quantity, the manufacturer determines the production batches. The paper investigates (also numerically) the effect of cooperation.

The second paper "Optimal dynamic pricing and ordering decisions for perishable products" was by Ek Peng Chew, *Chulung Lee* and Rujing Liu (National University of Singapore and Korea University) and was planned to be presented by Chulung Lee. Unfortunately he was prevented from coming, thus it was presented by *Ki-Sung Hong*. The paper dealt with the pricing and ordering decisions in case of perishable products that are mutually substitutable. The paper shows convincingly that in such a case it is important to consider the demand substitution effects between the products in determining pricing and ordering decisions. Numerical methods (exact and heuristic) were also presented.

The third paper **"A fuzzy cross-evaluation approach for multi criteria ABC inventory classification"** was by **Jaehun Park**, Hyerim Bae, Sungmook Lim and Joonsoo Bae of Pusan National University. The paper was about multicriteria ABC classification. One of the possibilities is to use DEA for this. The paper shows how the applicability of DEA is restricted and that a better possibility may be to combine it with a fuzzy cross evaluation method. One of the advantages is that this makes it easy to include judgments. Test results were also presented.

#### AUGUST 21, 2012 IM 3

by Lucio Zavanella

"The role of supply chain integration in increasing the "Snowball Effect" in the transmission of disruptions" by Artur Swierczek (author and presenter) – University of Katowice, Poland

The research method adopted in the study is based on the collection of information from companies. The particular aim of the survey was to understand and study the effect of disruptions in Supply Chains, thus appreciating its propagation in terms, e.g., of intensity, widespread diffusion and quickness. To this end, a preliminary classification has been introduced, distinguishing between forward, backward and two-ways transmission of the disruptive event. The propagation of the disruption has been described as the "snowball effect", where companies pertaining to the chain may suffer because of direct and indirect effects. According to the classification given, the framework adopted in the research focused on a three level chain (supplier, manufacturer, customer, thus capturing the whole classification introduced above) so as to explore the relationship, if any, between the Supply Chain integration level and the disruption propagation.

The investigation method, i.e. the survey and the consequent data collection, was based on a wide sample (216 companies), with a significant percentage of trading companies. In addition, the structure of the survey was intended to allow the quantification of the level of the integration of the Supply Chain the companies pertain to, thus assessing convenient clusters. The final result showed, within the sample investigated, a large number of fully integrated companies (43%). Thanks to the Likert scale adopted, the author avantified and appreciated the strength (intensity) of disruption propagation in the Supply Chain for each structure of the classification type. Data presentation and the related analysis allowed the author to draw interesting remarks and stimulate discussion. Among the results commented, evidence should be given to the fact that, in general, the "snowball effect" is particularly evident in fully integrated supply chains (especially, forward and backward transmission). Therefore, the integration level is critically related to disruption transmission, even though its impact varies within the category observed (e.g., information flow, material flow, financial flow). The complete analysis of the survey results could originate additional interesting remarks, e.g. addressing the strategies adopted by the companies to face disruptions and the differences between the different sectors investigated.

"Company competitiveness and inventory performance" by A. Chikán (author) – Zs. Matyusz (author and presenter), Corvinus University of Budapest, Hungary

The study may be introduced by an intriguing question: are inventories related to company competitiveness and, above all, in which way? The basic rationale was that inventories (once conveniently analyzed and measured) are an of strategies expression company and performance, also with respect to competitiveness. An answer to the question put may be searched by an accurate investigation of historical data, the subsequent formulation of reasonable theses and their validation. Since 1995, data on the topic were progressively accumulated at the Competitiveness Research Centre at the Corvinus University of Budapest and studies, already published on the topic, were presented as a source of the research, too. Accordingly, the presentation focused on what "competitiveness" should be intended for, in particular moving from a research-based definition (Chikán – Czakó, 2005). Key factors of competitiveness were identified (e.g., ability to change and capabilities) and the links between them were structured into the formulation of the "competitiveness index". The index aim is to encompass the (measurable) attitude of the company to face changes, according to market success. Data were collected on the basis of a wide survey (more than 300 answering companies and four times contacts), basically referring to 2005-2008 years. The composition of the sample appeared to be complete, mainly including manufacturing companies and, after them, services and commerce. The wide and mixed sample allowed an effective comparison of factors relevant to each sector, too. The questionnaire included inventory-related issues, thus allowing the researchers to investigate the relationships between inventory and competitiveness. For example criteria for inventory management, influence between financial factors and inventory, level and mix of the inventory itself, kanban and/or ERP use were offered as examples of inventory-related variables. The methodology used to analyze

data collected was also described. In particular, groups were identified and compared each other by significant and independent variables (noteworthy, inventory-related variables present meaningful differences among the groups identified on a competitiveness base). An appreciable conclusion addressed the identification of the most influential variables with respect to company competitiveness. These influential variables were identified as the comparison of inventory-level and inventory-mix with respect to the main competitor and the influence of financial opportunities on inventory level and policy. Also the presence of an inventory module in the ERP software was addressed as a significant influential variable.

"Determinants of input, work-in-progress and output inventory levels: an international study of manufacturing industries" by K. Demeter, (author), Corvinus University of Budapest, Hungary, and **R. Golini** (author and presenter), University of Bergamo, Italy

The presentation started by drawing a framework of inventory types in manufacturing and consequently putting two relevant research questions. Briefly, the authors started by classifying the forms that inventory may assume in manufacturing companies, i.e. raw materials, work-in-progress (WIP) and finished products. As these types of inventories differ in several features (e.g., cost, motivation, supply), the two arising questions concern (1) the main configurations in terms of level of inputs (such as raw materials and components), WIP and output (i.e. finished goods) and (2) which factors, if any, may explain these different configurations. So as to find the answers, the authors started exploring data from the 5<sup>th</sup> edition of the International Manufacturing Strategy Survey (2005-09, thus being data collected before and during the recent crisis) and also investigating the trends over the data collected in the past editions (i.e., since 1991 to 2009). Therefore, the extended time horizon, the international dimension of the survey and the wide set of data available presented the research as a promising way to gain insights into eventual relationships and information about

inventory types, their management and related strategies. Of course, given also the twodecades period of reference, the trends of data were discussed paying attention to the managerial principles which gained attention during the period considered (e.g., Lean Thinking advent, business cycles, adoption of techniques such as vendor managed inventory). A first outcome was the similarity between the input and output trend of the level (measured in days) and a little difference in the WIP one. The research also identified and focused on five different clusters of companies, organized on the basis of the level (Low or High) of the three inventory types, which also revealed to be configurations permanent over time. In particular, the most populated cluster resulted to be the LLL one, i.e. the cluster including those companies keeping the three inventory types at a low level, and this type of cluster resulted as the "expanding" one over the time horizon. The research also investigated, by ANOVA analysis, the relevant factors by identifying variables such as the company position in the Supply Chain, global sourcing, the material cost and others. Consequently, results were discussed examining the effects of the two most important explanatory variables (over the three types of inventories): decoupling point and type of production. The research development was also addressed, suggesting the inclusion of other factors and highlighting the opportunity for identifying strategies specific for each cluster.

# AUGUST 21, 2012 > IM 4

#### by Avijit Banerjee

The first paper scheduled in this session, titled "Simulation optimization for the stochastic economic lot scheduling model with sequencedependent setup times" (co-authored by Manuel Riel, Nils Löhndorf and Stefan Minner), was presented by *Manuel Riel*, Wirtschaftsuniversität Wien, Austria. The aim of this study is to determine the optimal sequencing and lot sizing policy, yielding minimum expected average total cost over an infinite planning horizon, for the stochastic economic lot scheduling problem (SELSP) with sequence-dependent setup times. A semi-Markov decision problem (SMDP) is formulated, incorporating compound Poisson product demands and lost sales, where the stage decisions for the process are: continue producing the same item, switch to a different item or allow the process to be idle. It is contended that this model cannot be solved in closed form and the dynamic programming approach is computationally too burdensome. Consequently, а simulation/optimization methodology is implemented and its performance is evaluated numerically. This approach involves a two-step iterative procedure combining direct policy search and heuristics for the embedded traveling salesman problem. First, the order-up-to levels and the production frequencies of the items are determined. For these frequencies, the second step attempts to find the optimum production cycle, employing three different approaches. The first is based on the common cycle concept. Under the second approach, the items are produced according to their frequencies. In both cases, the Lin-Kernighan heuristic is used for cycle time minimization. The third approach uses the notion of a balanced cycle, where the expected time between setups of the same product are balanced, using a modified k-opt heuristic for minimizing the cycle time. The results of a large-scale numerical study indicate that the balanced cycle policy outperforms the unbalanced cycle approach for 10 or more items. In addition, under asymmetric setups, allowing some products to be produced more frequently is superior to the common cycle policy.

The second paper, titled **"Inventory policies for ameliorating items"** (co-authored by Lucio Zavanella, Simone Zanoni and Ivan Ferretti) was presented by *Lucio Zavanella*, University of Brescia, Italy. This paper focuses on a special class of inventory items known as "ameliorating" items. Most of the existing literature concerning inventory management deals with items that preserve their value over the time they are stored. There is also a substantial body of work involving deteriorating and/or perishable products. Studies that examine inventory items that increase in value while they are in storage, however, are relatively rare and far between. In view of the fact that products that appreciate in value over time are not uncommon in practice, it is somewhat surprising that the first paper dealing with such items was published in 1997 and since then has received relatively scant research attention. This paper represents an effort to fill this gap in the current body of knowledge. Some noteworthy examples of ameliorating inventory items, such as aged cheese, red wine, whiskey, etc. can be found largely in the realm of food and beverage production and supply. Such products, while in inventory, can command an increasingly higher market price, as they age over time. Moreover, the market demand for an ameliorating item is likely to be a function of its price. Considering the fact that warehousing capacity is limited, and that specific environmental and storage conditions may often be necessary for proper aging, the relevant managerial decisions involve the quantity of each such item to be stored and the amounts and timings of its sales. Towards this end, a mathematical model, with a profit maximization objective function, is constructed. The costs considered include the fixed costs of production and moving a product to the storage location and the variable costs of holding inventory over time. It is proposed that this model will be adapted and tailored to actual applications to be found in the real world, leading to important managerial guidelines for specific instances of ameliorating item inventory management.

The final paper of the session, "A newsvendor model with dual sourcing under risk aversion and order-dependent lead times" (co-authored by Christoph Glock and Jörg Ries) was presented by Christoph Glock. Technische Universität Darmstadt, Germany. This study examines a product newsvendor model under sinale uncertainty, where a risk-averse buyer (i.e. retailer) can source the item from two suppliers with different production technologies. For each supplier, the delivery lead time increases with the replenishment order quantity. In comparison with previous research on dual sourcing, this is a distinguishing feature of this paper. The retailer's

total order quantity is split among the two suppliers, each of which initiates production with the receipt of the order and delivers the quantity ordered after the passage of the quantitydependent lead time. The risk preferences of the retailer are modeled via a mean variance approach. Depending on the timings and sizes of the retailer's orders, its overall stock level, as well as the supply related risks can be reduced, albeit at higher order processing and handling costs. Another effect of such dual sourcing, with delayed order release, is a reduction in the overall procurement lead time, resulting in the added benefit of forecast error reduction in estimating the product's demand over the sales period. Under certain circumstances, the scenario of the retailer's ability to order a part of its replenishment quantity from a second source, relatively close to the sales period, bears some resemblance to single sourcing newsvendor models with a second opportunity to order. The results of an extensive numerical study performed in this paper indicate that in certain cases, a dual sourcing policy can be substantially advantageous from the retailer's perspective, especially when it is highly risk-averse. In such cases, the structural supply chain redundancies, as a direct consequence of dual sourcing, provide the retailer with a mechanism for hedging against the uncertainties resulting from quantity-dependent delivery lead times. In addition, as the retail price increases, order splitting between two suppliers tends to result in a larger total replenishment order quantity on the part of the retailer, in comparison with the single sourcing scenario.

# AUGUST 21, 2012 > IM 5

by Jukka Korpela

There were two presentations in this session. **"Inventory location and transshipment problem"** by **Oded Berman**, University of Toronto, Canada

Oded Berman presented new insights into an inventory location problem where transshipments between facilities are allowed and the shopping

patterns of customers can vary depending on stock availability in different facilities. Dr. Berman had applied the Infinitesimal Perturbation Analysis (IPA) algorithm to solve this challenging problem. As suggested by Dr. Berman, the results he showed brought some interesting new insights to this research area.

"Facility location for inventory reduction: A practical update on p-median heuristics" by Geraldo Ferrer, Naval Postgraduate School, USA

Geraldo Ferrer applied different heuristics techniques to determining the location of distribution centers for a network of usage locations. Specifically, Dr. Ferrer used the problem of identifying the ideal locations for fighter jet spare engines for 33 bases of US Air Force in 2008 as the case where he applied and compared several seminal heuristics. The study suggests that there is a need for reviewing the past results in Operations Management as the computing power has increased significantly. The presentation by Dr. Ferrer provided interesting results on how efficiently different heuristics support solving distribution center location problems.

#### AUGUST 21, 2012 > IM 6

by D. Clay Whybark

Three papers were presented during this session.

The first paper referred to "Global dual sourcing and order smoothing". It was presented by Jan A. Van Mieghem from the Kellogg School of Management at Northwestern University in Evanston/USA and co-authored by Robert N. Boute. A dual sourcing policy was studied that reflected the interaction of a cheap but slow offshore source and a fast but expensive local supply facility. It was shown that by the adoption of a linear control rule an exact and analytically tractable analysis of a dual sourcing and mixed mode transportation policy is possible. For a lead time difference of one review period an exact lower bound formula on the home base or offshore allocation was given. For longer lead time differences close approximations were provided. It was shown under which practical conditions the dual sourcing smoothing policy is advisable or even better than other policies.

The second presentation was given by Rene Haijema from Wageningen University in The Netherlands who talked about "Optimal issuance and depletion of perishable products under a periodic order-up-to S policy". A stochastic inventory control problem for perishable products was addressed where replenishments follow an order-up-to S policy. It was investigated whether a clever issuance policy helps to improve the performance of inventory systems of perishables with a short fixed shelf life. Simple depletion policies known from practice like FIFO and LIFO rules were compared with the optimal issuance policy developed by a stochastic dynamic programming approach. A major conclusion was that the performance of inventory systems often can be improved by simple depletion policies so that complex stock age dependent policies not necessarily have to be considered.

In a third presentation, Kaj Rosling from Linnaeus University in Vaxjo/Sweden gave a report on a paper (co-authored by Mojtaba Farvid) entitled "Customer waiting times in (nQ,R) inventory systems with compound Poisson demand". First, the customer waiting time was introduced as critical variable in heuristic modelling of multiechelon inventory systems that is not yet sufficiently investigated in the literature. For (nQ,R) inventory policies with continuous review and compound Poisson demand an extension of the analysis of customer waiting times for the special case of R+1<0 was presented. In this context, the cases of partial as well as of full deliveries of customer demand were considered. The probability distributions of the customer waiting times were characterized and exact and approximate formulae for means and variances were derived.

#### AUGUST 23, 2012 > IM 7

#### by Petri Niemi

In the first presentation Harmen Bouma from University of Groningen, The Netherlands, gave a high quality presentation on topic "A heuristic approach to the inventory pooling and routing problem". The paper is co-authored by Ruud Teunter from the same university. The presentation dealt with a problem of A distributor of paint in the Netherlands which supplies number of retailers periodically, has no stock on hand between replenishments and rebalances stock levels of retailers somewhere during the period. The work aimed to answer questions what are the optimal order-up-to levels for the retailers, and how and when to redistribute stock.

In the second presentation, "A simple heuristic for vehicle routing and keeping low transport inventories - A variant of Clarke and Wright's saving method" professor Anders Segerstedt from University of Technology, Luleå Sweden presented a simple heuristic method developed originally to solve the problem how to teach students the routing algorithms. As a result the programming of the modified Clarke and Wright saving method is easy and it has also been found to give good results in first tests. Finally he addressed his interest to find research partners to test the method in a real-world problem.

The third presentation "Deriving research agendas for manufacturing and logistics systems: a methodology" given by professor Maurice **Bonney** from Nottingham University Business School, United Kingdom, presented a methodology for an important issue in OM research: how to derive research agendas for logistics and manufacturing systems. The presented five-staged methodology helps especially manufacturing and logistics systems analysts to identify and prioritize an organization's problems and so to determine the changes that need to be made. However, it is obvious that the methodology could be adapted also to other research areas. The paper "Deriving research agendas for manufacturing

and logistics systems: a methodology" was written by Maurice Bonney together with Mohamad Jaber from Ryerson University, Canada.

# AUGUST 24, 2012 > IM 8

#### by Krisztina Demeter

This session was a long one with four presentations. Three of them had some relation to environmental issues and used modeling techniques to discuss their specific topic. One discussed a managerial issue using a case study as illustration. We had a relatively large and active audience, ranging between 13-25 people during the session.

The paper titled as "The single-period inventory model with product-carbon footprint constraint" was presented by Werner Jammernegg (coauthored by Emel Arikan) from Vienna University, Austria. After illustrating the importance of sustainability issues and introducing the modeling methods and earlier works available to incorporate sustainability, the speaker described the key features of their inventory model. Starting from a single sourcing setup, they extended it to a dual sourcing newsvendor problem, using the product-carbon footprint as a constraint, and assuming two orders, the first order based on make to stock, while the second order is based on make to order (extra demand) sourcing. They built three scenarios, where the two deliveries 1) are from the same vendor, 2) are from different sources, the second delivering faster, 3) are from different producers working in different countries (offshore first, onshore second). The authors drew several conclusions examining the scenarios one by one. The overall conclusion for all the scenarios is that there is a potential negative impact on economic performance for products with high optimal (first) order quantity. Furthermore, more risky demand has higher negative impact on performance.

"Returnable transport items" (RTIs), such as pallets or containers, were in the core of the presentation by Cristoph H. Glock (Darmstadt University of Technology, Germany). This paper titled as "A joint economic lot size model with **RTIs"** was jointly written by Taebok Kim (University of Incheon, South Korea). RTIs are rarely in focus of investigations, although investments and costs related to these items can be very high. The authors developed a model of a supply chain that considers both the downstream flow of materials from the manufacturer to the buyer, as well as the circulation of RTIs between the two actors. The model is solved by non-linear programming and a heuristic, and also a simulation study was performed. The aim was to study how many RTIs should be installed, which shipment policy for materials and RTIs should be used from the manufacturer to the buyer, and how the RTIs should be returned from the buyer to the manufacturer.

Jekaterina Ossipova (Tallinn University of Technology, Estonia), PhD student, presented a case study on "Inventory optimization using ABC/XYZ matrix analysis for a furniture retailer". In her presentation she introduced the essence of ABC (ranking items according to the annual turnover, profitability, turnover ratio, etc.) and XYZ analysis (analysis of the usage/consumption regularity), highlighting that the two approaches are rarely used one by one, or together. Applying the two approaches for a furniture company she detailed the principles they used and the strategies they developed after classifying the items into various categories proving the efficiency of combining the two approaches. I believe that this case study can be used well for teaching purposes, and due to its simplicity it might be very useful for practice, as well. The audience tried to help the author to improve her paper, considered as the basis of her PhD thesis.

S.M.J. Mirzapour Al-e-hashem (Emlyon Business School, France) examined a novel model for transshipment enabled inventory routing problem (IRP) in a many-to-one supply chain with his coauthor, Yacine Rekik. The paper is titled as **"A** robust stochastic programming model for a transshipment enabled inventory routing problem". According to the presentation, IRP

combines vehicle routing and inventory management (vendor managed inventories), analyzing the decisions of when to deliver, and how much to deliver to the customer, as well as the decision about the delivery route to use. The contribution of this paper is, that it strives to green the supply chain using two stage robust stochastic programming and a scenario-based approach. It allows demand uncertainty, transshipment, various vehicle types (with different emissions), and capable to optimize multiple objectives.

#### AUGUST 24, 2012 > IM 9

by Anders Segerstedt

In this session four papers were presented:

# Peng Sun, Duke University, USA and Paul Zipkin "A new algorithm for lost-sales inventory control"

The paper proposes a new approach, based on approximate dynamic programming, for the classic lost-sales inventory problem in discrete time with stochastic demand and a positive lead time. The exact function is approximated by linear combinations of simple functions with the same property. A weighted sum of outstanding orders instead of the standard inventory position is used to accomplish a fairly simple heuristic policy. Numerical tests indicate that this policy performs quite well.

# Grigory Pishchulov, TU Dortmund University, Germany, Knut Richter and Sougand Golesorkhi "A single supplier-single buyer bargaining model with asymmetric information and partial vertical integration"

This work introduces a model of the partial vertical integration based on the work of Sucy [A bargaining model with asymmetric information for a single supplier single buyer problem, EJOR,171, p 516-535, 2006]. Both Sucy's model and his optimality analysis are extended to the case of the partial vertical integration by assuming that the buyer has a share in the supplier. A series of numerical experiments is



conducted to capture the dependence of the supplier's barging surplus and optimal contract choice on the ownership share of the buyer in the supplier.

# Mikael Collan, Kaj-Mikael Björk, and **Kalevi Kyläheiko: Evaluation of an information systems investment into reducing the bullwhip effect**

A methodology for the profitability evaluation of an information system investment is presented, especially for reducing the bullwhip effect in the supply chain. The bullwhip effect costs but it can be counteracted by smart decision making using smart collaborative methods. A fuzzy pay-off method is applied into the bullwhip context. The investment of smarter information systems can lead to an improved inventory and supply chain performance.

# Chulung Lee, Korea University, South Korea, and Shuai Yang "Supply chain coordination with stock-dependent demand rate and credit incentives"

A supply chain which consists of a single manufacturer and a single retailer with a single product type is considered. The consumption rate is assumed to be dependent on the retailer's stock level. Three cooperative policies to coordinate the manufacturer and retailer's decisions are presented. A centralised supply chain policy is shown to achieve coordination. Under all three policies there are optimal order quantities to maximise both parties' profit. Some numerical examples illustrate the proposed policies.

# AUGUST 24, 2012 > IM 10

#### by Ruud Teunter

The first presenter was **Karin de Smidt-Destombes**, University of Amsterdam, The Netherlands who presented joint work with Iris Vis on **"Sequencing methods for storing and retrieving inventories"** This research is highly innovative as it considers multiple cranes per aisle whereas almost all of the literature is limited to a single crane. An LP formulation and heuristic were presented for minimizing the total work time, with very encouraging savings from using multiple cranes per aisle.

Andrea Ferrara, University of Modena and Reggio Emilia, Italy also talked about warehousing, based on joint research with Andrea Grassi and Elisa Gebennin. His topic was that of "Joint design of LGV pallet shuttle fleets for warehouse automation". To be more specific, he discussed emerging technologies for multi-pallet deep storage racks. A model was proposed that evaluates the pallet shuttle utilization rate as a function of the number of Laser Guided Vehicles (LGV's), and validated by discussing a real life case.

Finally, **Steffen Klosterhalfen**, BASF SE, GVM/S, Germany presented joint work with Josef Kallrath and Gerd Fischer on **"Rail car fleet design: Optimization of structure and size"**. He showed for a real-life case in the chemical industry that by reducing the number of different rail car types that a company uses, the required switching effort can be reduced drastically. Moreover, by designing a MILP model for minimizing rail car cost, this can be achieved without a large cost increase. Indeed, numerical results for the considered case indicate that it is best to use only one more rail car type than the minimum that is needed to satisfy all types of requests.

To conclude, this was a very interesting, highly innovative session on warehousing and fleet design.

# AUGUST 24, 2012 > IM 11

#### by Chulung Lee

There were two papers presented in this session.

Stephanie Vogelgesang from the University of Magdeburg in Germany presented her work, "Solving the disassemble-to-order problem under yield process misspecification", which is a joint work with Ian M. Langella and Karl Inderfurth. The authors studied the disassemble-to-order (DTO) problem in a remanufacturing industry. The DTO problem deals with the question of how to decide the amount of returned products to disassemble in order to meet a specific demand of different parts of the product. Since there exist quality differences among the returned products, a random yield problem for the number of good quality parts obtained from the disassembly process is considered. Randomness is modeled in two different ways in order to incorporate random yields into a DTO problem; proportional random yields (SP) and binomial random yields (BI). The SP presumes that the yield rate parameters do not change by increasing or decreasing the number of products to disassemble while the BI does not require this assumption but is considerably more complex to analyze. In this study, the authors have tested if one of the approaches is better fitting the disassembly outcome using actual yield data from a car engine remanufacturer and conclude that none of the yield modeling approaches can be used exclusively for all parts of the engine to represent the outcome of the disassembly process. They also examined the impact of using a wrong approach in decision support and calculated the performance loss of misspecification of the yield model as a relative cost deviation. From the numerical results, the authors identified the cases in which misspecification of the yield type has stronger effect on the cost performance.

Secondly, **Shuoguo Wei** from the Linköping University in Sweden presented a joint work with Ou Tang; the presentation was entitled

"Managing cores for remanufacturing during the product life-cycle". The main contribution of the presented research work was to propose an optimal control policy to determine how to manage collecting cores at different stages of a product life-cycle, which is critical in a remanufacturing industry. Without enough cores, remanufacturing production lacks the raw materials and its process may be interrupted, resulting lost sales in the market. While too many cores may become obsolete. Therefore, there is a necessity to maintain the appropriate amount of core inventories by collecting and disposing them. In this work, the authors considered the product life-cycle and assumed that the availability of core is changing along with time and the demand of remanufactured products is quite different along the life-cycle. The authors applied the diffusion model to describe the dynamics of core availability and demand of remanufactured products, In order to maximize the profit of the remanufacturer over the entire life-cycle, the author proposed a mathematical model to determine the quantity of core at different stages of product life-cycle and developed several heuristic strategies.

#### AUGUST 24, 2012 ▶ IM 12

by Yoshiki Matsui

Geoffrey Relph, Inventory Matters Ltd., UK -Michael Newton "Both Pareto and EOQ have limitations, combining them delivers a powerful management tool for MRP and beyond"

Based on the observation that parameter management continues to be an issue in MRP systems and optimising tools are still mostly manual, this presentation proposed an interesting combination between two popular and powerful analytical tools for MRP and other practical production planning approaches. That is a merger of Pareto analysis and EOQ formula, which leads to the exchange curve or K-curve by logical extension of both theories. The order frequency is based on the EOQ logic and used to divide Pareto in to more than three classes. The use of K-curve is supposed to be simple and effective a strategic, tactical and operational tool, requiring the same data that is used to construct the Pareto and less data than is needed to solve EOQ. Some practical questions and discussion followed after the presentation.

Alexander Dobhan, University of Bamberg, UK – Michael Oberlaender: "Behavioral analysis and adaptation of a negotiation based, quantitative planning approach for hybrid organizations"

They started with two important behavioural patterns in the newsvendor supply chain situation (risk aversion and pull-to-center behaviour) and presented the results from their analysis of a hybrid coordination problem where a central unit or contract determines general conditions and coordinates the solution process and decentralised units detect and communicate their locally best solutions without releasing private cost information. They concluded that hybrid approaches are robust against behavioral deviations and that units with a pull-to-center behavior have an disproportionately high impact on the hybrid approach quantity, while single riskaverse sites have an disproportionately low impact on the hybrid approach quantity. They also proposed an experimental design of the hybrid coordination with undergraduate students, which was followed by a couple of interesting questions and interactions.



# **Mathematical Modelling**

## AUGUST 20, 2012 Modelling 1

by Henk Zijm

An analysis of the effect of response speed on the bullwhip effect using linear control theory

Maximiliano Udenio - Jan C. Fransoo - Nico P. Dellaert, Eindhoven University of Technology, Eindhoven, the Netherlands

In this paper, linear control theory is used to analyze the effect of dynamic inventory policies on the non-stationary performance of order and inventory behavior throughout a supply chain. The analysis of this paper starts with the observation of a worldwide bullwhip effect following the financial crisis of September 2008. Many companies attempted to retain liquidity by reducing their inventories, but if many companies along a supply chain do so simultaneously, a bullwhip effect is a natural consequence. The authors provide an analytical explanation to their previous research on the use of system dynamic simulations, with explicit attention to modeling managerial behavior. In particular, the use of different behavioral parameter settings and through that the study of a variety of order behaviors forms a welcome addition to the literature.

This presentation is highly actual in the course of the continuing financial problems in a large number of countries throughout Europe (much



less in the Far East) and was based on a sound theoretical framework. It gave nice insights into inventory dynamics (a field going back to the Industrial Dynamics paper by Forrester in the late fifties), in particular in times of financial turmoil. Maximiliano Udenio clearly expressed his maturity in this research area. The paper was well received by the audience.

# A vendor managed inventory model with transportation to geographically dispersed retailers

**Christian Larsen** - Marcel Turkensteen: Aarhus University, Department of Economics, Denmark

In this paper, the supply of materials to a set of geographically dispersed retailers is studied, where the geographical locations of the retailers is explicitly accounted for, contrary to the classical Joint Replenishment problems often used in a Vendor Managed Inventory environment. In particular, the transportation costs arising from these different locations may play a role, in particular when retailers are grouped into routes to be delivered by a truck in one route. This defines a joint transport and inventory problem for which a Markov chain model is in principle appropriate. However, here the curse of dimensionality holds, leading the authors to approximate the lengths of the delivery tours by a so-called continuous approximation approach, where two different service areas are distinguished that are basically two extremes: a circular area and a line (both holding a number of destinations). In additions, zones are defined such that deliveries per zone are considered. First numerical results are promising but more research is needed.

The presentation by Christian was well done, but this research paper leaves quite a number of problems open. Attention was paid to negative effects (e.g. carbon emission) but in particular future strict legislation (think e.g. on city distribution problems) may influence the choice of delivery strategies. In view of in particular environmental problems, and therefore the need to bundle freight deliveries to reduce the number of transport kilometers made, still much work has to be done.

# Sea-based military logistics for aerial distribution to support combat units

Shi W. Lee - Ilkyeong Moon - Jeong-Hun Lee: Dept. Of Industrial Engineering, Pusan National University, Busan, South Korea (address of first two authors)

In sea-based military logistics, amphibious ready group ships are used to provide a sea-base from which combat forces ashore are directly sustained. Hence, instead of using land-based support units, all supplies are stored on a floating sea base, primarily for safety reasons. Supplies from a sea-base are directly delivered to combat units in operation by aircraft. The paper studies various models for supporting combat units ashore, based on mixed integer linear programming with a goal to minimize the number of aircraft take-offs to reduce the risk of land-to-air attacks. Efficient heuristic algorithms and in particular a genetic algorithm have been developed that produce very satisfactory results in medium- to large-sized warfare scenarios. In particular, the genetic algorithm proves to be highly robust with respect to problem size variation and requires only short computation times.

Shi Lee gave an enthusiastic presentation on a problem that was obviously new to the far majority of the audience. At some point in time, there was a bit too much detail on the models that made the presentation a bit hard to follow. However, the topic is highly significant in view already of the (sad) observation that the number of military crises seems to expand rather than diminish. It is beyond doubt that safety of supplies to combat units is of key importance to the success of military operations. This topic will certainly return more frequently on the research agenda.

# AUGUST 20, 2012 > Modelling 2

#### by Robert Grubbström

In the Monday afternoon session on Mathematical Models of Inventory, three interesting papers dealing with different subjects were presented. The first paper "On the Equivalence of Inventory Models Based on Classic and Net Present Value Principles" authored by Patrick Beullens, University of Southampton, and Gerrit K. Janssens, University of Hasselt, was a follow-up of an article recently published in the European Journal of Operational Research. It introduced the notions of equivalence, perfect equivalence, and nonequivalence, using concepts from set theory, in order to provide examples of models by which the equivalence of applying the classical Average Cost and the Net Present Value as criteria were to be established.

Of specific interest was the inclusion of some classic examples for which the equivalence between the two criteria could not (yet) be established and where the two criteria produced significantly differing results. This led to the conclusion that such models should be given serious attention as to the validity of the inventory policies that they suggest.

On a different theme, the second paper entitled "Customer Satisfaction and Lead-Time Quotation in an M/M/1 Base-Stock System" and authored by Koichi Nakade and Hiroki Niwa, Nagoya Institute of Technology, treated a model of the base stock type applying a Poisson input of requests and an exponentially distributed service time for satisfying these requests. Customer utility was at the focus, in particular concerning the disutility of long waiting times leading to customers leaving the system. Lead times were quoted endogenously, and the problem was to determine the optimal policy for how the leadtime quotes should be made.

It was discussed how the lead time quotation policy in a base stock system sometimes could have a win-win consequence, enabling both a higher system profit and a higher customer satisfaction.

The third paper was entitled **"Lead-Time Investigation and Estimation**" authored by **Mojtaba Farvid** and Peter Berling, Linnaeus University, Växjö. In this paper a large simulation study of a two-level distribution system was investigated. Consequences from different decision variables as well as from different external parameters influencing the lead-time were studied. Also a simple method to estimate the mean and variance of the lead-time was presented. With this method the stochastic leadtime demand at the central warehouse was exchanged for a stochastic demand rate.

As expected, both the expected value and the variance of the lead-time increased with the order quantity of both the retailer and the central warehouse. This could be interpreted as an "inverted bullwhip effect".

# AUGUST 21, 2012 > Modelling 3

#### by Ilkyeong Moon

Three papers were presented in this session. The common theme of the three papers is inventory modeling even though all of the three papers used different methodologies. At the beginning of the session, there was an audience of 10 people. However, when the last speaker, Jacob Wijngaard (fellow of ISIR and former ISIR president), started his presentation, there were no empty seats in the session. A live questions and responses followed after the presentation.

## "Optimal replenishment schedule for finite horizon models" by *Lakdere Benkherouf* from Kuwait University, Kuwait.

The author is a frequent participant in ISIR and has studied theoretical inventory modeling for a quite long time. In this study, Benkherouf tried to find a unified approach for finding the optimal inventory policy by utilizing the general methodology developed by Benkherouf and Gilding (2009). They formulated a class of single item economic lot-size inventory models using a mixed integer nonlinear program. Benkherouf showed that the optimal policies for several inventory models can be treated using the approach proposed by Benkherouf and Gilding (2009) even though the degree of smoothness required by the method may limit its application.

"Dynamic supply chain inventory management under deterministic and uncertain conditions: A generic mathematical programming approach" by Joaquim Vicente, Susana Relvas, Ana Barbosa-Póvoa from Technical University of Lisbon, Portugal. This study was presented by Vicente. This study considered a supply chain consisting of multiple warehouses, multiple retailers, and multiple products over the multiple periods. The authors modeled the supply chain using a mixed integer linear program, and compared a general inventory management (IM) policy with a continuous review (CR) policy and a periodic review (PR) policy. Even though the authors claimed that the IM policy outperformed the CR and PR policies, several attendees including myself suspected that there might be some flaws in the mathematical model which should be clarified.

"On optimal policies for production inventory systems: The combination of set-up costs and order acceptance" by Jacob Wijngaard and Nicky van Foreest from University of Groningen, The Netherlands. This study was presented by Wijngaard. Distinguishing between various classes of demand arises frequently in practice. Rationing polices have been widely studied after Kaplan and Veinott independently published their studies in Management Science and Operations Research in 1965. Wijngaard considered a single-item, single-machine production system with compound Poisson demand. When the order (with different reward) arrives, we need to decide whether we should accept or reject it. This study is an extended version of Ha (1997, 2000) in which setup cost is not considered. The structure of the optimal policy including the monotonicity of production decisions was investigated.



#### AUGUST 21, 2012 Modelling 4

#### by Werner Jammernegg

In this session all three scheduled papers were presented. The presentations were attended by 10 to 20 participants, which also led to interesting discussions.

The first paper on **"Energy for stabilisation of perishable goods in cold logistic chain"** was presented by **Marija Bogataj**, MEDIFAS, Mediterranean Institute for Advanced Studies, Slovenia with co-authors David Bogataj and Robert Vodopivec. The topic was motivated by a supply chain for pharmaceutical products that have to be cooled to maintain the required level of quality. The problem formulation obtained in the time domain was compared with that in the frequency space that was introduced by Grubbström. If the cost of energy is not negligible energy must be incorportated in an extended Manufacturing Requirements Planning framework.

Xuehao Feng from Pusan National University in Korea presented the second paper in the session entitled **"Coordination of supply chains under budget constraints"**. The co-authors *Ilkyeong Moon,* Kwangyeol Ryu and Sungchan Kim are from the same university. Based on the deficiencies of the revenue sharing contract and the buyback contract the authors propose a composite revenue-sharing-and-buyback contract (RB). Considering capital cost in the budget constraints it is shown that only the RB contract coordinates the investigated two-stage supply chain.

The third paper on **"Performance of the Clark-**Scarf algorithm in multi-echelon inventory systems with lost sales" was presented by *Marco Bijvank* from Erasmus University Rotterdam, The Netherlands, with co-authors Tim Huh and Ganesh Janakiraman. The basic research question was to investigate the quality of the class of order-up-to policies that are known to be optimal in the corresponding backordering model. A large number of experts in this area attended the talk which led to a vivid discussion already during but also after the presentation.

#### AUGUST 21, 2012 Modelling 5

#### by Adriana Gabor

The speaker of this session came from Germany, India and Japan.

Karl Inderfurth, Otto-von-Guericke University of Magdeburg, Germany "Steady-State Analysis of Linear Control Rules in Random Yield Problems"

In this presentation, a linear control rule for an inventory model with yield uncertainty was discussed. In the considered rule, the size of an order is proportional with the difference between the safety stock and the expected inventory position at the beginning of the period. The expectation and variance of the net inventory and of the order size were obtained via a steady state analysis. Assuming further that the net inventory is normally distributed with the found parameters, the safety stock that minimizes the long run average costs was obtained. The presentation concluded with a sensitivity analysis.

Priyanka Chaturvedi, Ashutosh Sarkar, G. C. Majumdar, Sarada Prasad Sarmah, Indian Institute of Technology Kharagpur, India, "Milk procurement of a diary firm: an economical analysis"

The problem discussed in this presentation concerns the milk procurement of a private dairy in India that buys milk from farmers and through intermediaries and processes. The intermediary may also choose to supply a part of its milk to the local market. The authors presented two mathematical models to analyze how the private dairy can ensure availability at optimal cost in different situations. In the first model, it was assumed that the quantity supplied by the intermediaries is considerable to influence the local market price, while in the second, the price in the local market is fixed and the quantity supplied by intermediary to the local market depends on the difference in offered unit price b/w local market and processing unit. Based on two case studies, the authors have drawn several conclusions regarding the influence of the price variation in local market on the behavior of farmers and intermediaries.

#### Shusaku Hiraki, Hiroshima Shudo University, Japan "Hub-and-Spoke Shipping Approach to the ICGCPS"

The subject of the talk regarded a two phase model for determining the routes and the quantity of the products to be transported in a supply chain for the automotive industry. In the first phase, an integer program was formulated to find the transportation routes that minimize the CO\_2 emission. In the second phase, the maximum flow of products is minimized, under the additional constraint that the total CO\_2 emission is below a factor of the emission obtained in phase one. The presentation was concluded with the discussion of a numerical example.

#### AUGUST 23, 2012 > Modelling 6

by Karl Inderfurth

Three papers were presented during this session.

The first paper referred to "Global dual sourcing and order smoothing". It was presented by Jan A. Van Mieghem from the Kellogg School of Management at Northwestern University in Evanston/USA and co-authored by Robert N. Boute. A dual sourcing policy was studied that reflected the interaction of a cheap but slow offshore source and a fast but expensive local supply facility. It was shown that by the adoption of a linear control rule an exact and analytically tractable analysis of a dual sourcing and mixed mode transportation policy is possible. For a lead time difference of one review period an exact lower bound formula on the home base or offshore allocation was given. For longer lead time differences close approximations were provided. It was shown under which practical conditions the dual sourcing smoothing policy is advisable or even better than other policies.

The second presentation was given by **Rene Haijema** from Wageningen University in The Netherlands who talked about "Optimal issuance and depletion of perishable products under a periodic order-up-to S policy". An stochastic inventory control problem for perishable products was addressed where replenishments follow an order-up-to S policy. It was investigated whether a clever issuance policy helps to improve the performance of inventory systems of perishables with a short fixed shelf life. Simple depletion policies known from practice like FIFO and LIFO rules were compared with the optimal issuance policy developed by a stochastic dynamic programming approach. A major conclusion was that the performance of inventory systems often can be improved by simple depletion policies so that complex stock age dependent policies not necessarily have to be considered.

In a third presentation, Kaj Rosling from Linnaeus University in Vaxjo/Sweden gave a report on a paper (co-authored by Mojtaba Farvid) entitled "Customer waiting times in (nQ,R) inventory systems with compound Poisson demand". First, the customer waiting time was introduced as critical variable in heuristic modelling of multiechelon inventory systems that is not yet sufficiently investigated in the literature. For (nQ,R) inventory policies with continuous review and compound Poisson demand an extension of the analysis of customer waiting times for the special case of R+1<0 was presented. In this context, the cases of partial as well as of full deliveries of customer demand were considered. The probability distributions of the customer waiting times were characterized, and exact and approximate formulae for means and variances were derived.

# AUGUST 23, 2012 > Modelling 7

by Christian Larsen

The session was attended by approximately 15 people in each of the, in all 3, presentations.

"Cumulative staircase considerations for dynamic lotsizing when backlogging and/or lost sales is allowed" *Robert W. Grubbström*, Linköping Institute of Technology, Sweden and Mediterranean Institute of Advanced Studies, Slovenia

First was given a review of the classical lotsizing model of Wagner-Whitin and why the innercorner property is valid for both the variant of minimizing average costs or of minimizing total discounted costs. Then, it was illustrated the how to adapt the inner-corner property to cases where there is a finite production rate and when backlogging is allowed. Finally, the more complicating issue when having lost sales was addressed.

## "A new heuristic for the dynamic lotsizing problem with returns and remanufacturing" Onur A. Kilic, Haceteppe University, Turkey

The presentation addressed an adaptation of the classical lotsizing model when there is, in addition to a given demand stream, also a given return stream of reusable products. So, besides making decisions about when to start production of new products, one must also make decisions of when to remanufacture returned products. As the mathematical model is roughly a duplication of the classical model, and therefore can be of some considerable size, the focus was on studying various heuristics for solving the problem. A numerical experiment was presented and the results were compared to some previous studies. In finalizing, some extensions of the model, for example to include various aspects of randomness, were discussed.

"Production planning of a perishable product with lead-time and non-stationary demand" *Karin Pauls-Worm, René Haijema*, Eligius M.T. Hendrix, Roberto Rossi, Jack G.A.J. van der Vorst, Wageningen University, The Netherlands

This work is based on an application for the grocery sector, where many food products (like cheese) can have a rather long shelf life before perishability and the demand is usually non-stationary and stochastic. As a mathematical model for such a case can be intractable, a deterministic integer programming model was proposed as an approximation, in order to compute time dependent (indexed by t) ( $R_t$ , $S_t$ )

policies. Some numerical results were presented. Some possible extensions of the model, like to include a stochastic delivery lead-time, was discussed in the end of the presentation.

# AUGUST 23, 2012 > Modelling 8

#### by Sandra Transchel

The session comprised three interesting talks by Soren Glud Johansen, Dept. of Mathematics, Aarhus University, Gudrun P. Kiesmüller, Christian-Albrecht-University, Kiel, and Daquin Wang, Dept. of Management and Engineering, Linköping University.

# Soren Glud Johansen, "Emergency orders in an inventory system facing compound Poisson demand"

Soren presented an inventory control model which allows for normal orders, fixed to a quantity Q, and emergency orders with a shorter lead time than normal order but incurring additional cost. He presented a discrete-time Markov decision model and showed that the value for Q, which is determined from an optimal (R,Q)-policy for a system without emergency orders, performs quite well. He implemented the model by a value-iteration algorithm (VIA) for a continuous review system with compound Poisson demand. In a simulation study, Soren showed that his proposed model outperforms a heuristic decision rules suggested by Axsäter (EJOR 2007), except when demand is pure Poisson or when units cost for normal and emergency orders are the same. A fruitful discussion, in particular with Sven Axsäter, finalized his presentation.

## *Gudrun P. Kiesmüller,* "The fill rates for a critical level policy when demand is modeled as a compound Bernoulli process"

Gudrun studies a single-location, single-item inventory control problem where the available inventory is used to satisfy two types of customers with different priority. She presented a critical-level policy for a periodicreview, reorder point inventory system with intermittent demand. A critical-level inventory policy is characterized by the fact that low-priority customers are only satisfied, as long as the inventory level is above a critical level, whereas high-priority customers are always satisfied. The intermittent demand is modeled by a compound Bernoulli process. Gudrun presented

an approximation for the fill rate. In a numerical study she presents shows the importance of considering specific demand structures and the superiority of her approximation against others.

# Daquin Wang, Ou Tang, "Inventory stacking wit stochastic arrivals and departures"

Daquin presented an inventory stacking problem particularly motivated from the steel industry. Batches of finished products, which belong to different customers, stochastically arrive from a workshop and have to be stacked into storage slots to wait for departure. Later lorries arrive and retrieve products belonging to the same customer, which may cause a complex reshuffling of products as they are stocked in different storage slots. As the finished products are quite heavy and reshuffling is cost and time consuming, the object is to minimize the number of reshuffles and to improve operational efficiency. Even though this inventory stacking problem is similar to the container stacking problem in container yards, this work provides novel insights as both arrival and departure process are uncertain. Daquin proposes several models to minimize the number of reshuffles. Moreover, he presents two heuristics (TIGHT and LOOSE) and examines its applicability in industry. A simulation study compares the models and the two heuristics in various scenarios with a random stacking policy which generates an upper bound. The results of this research provide highly relevant decision support for the steel industry and improve operational efficiency and also the capacity utilization.

#### AUGUST 24, 2012 > Modelling 9

#### by Ou Tang

This morning session included 3 interesting papers. The session began with about 8 audiences (due to the good evening event on Thursday) and then increased to around 25.

Chi Chiang, and *Hui-Lan Hsu*, National Chiao Tung University, Taiwan **"An order fulfillment model with a periodic allocation review mechanism in foundry fabs"** 

Based on the case of electronic industry where demand is volatile and capacity utilization is high, the authors proposed a model to revise the available-to-promise (ATP) computation in production planning process. With a periodic review mechanism of updating demand information, in particular the cancellation of committed orders, this system re-allocates ATP quotas. Study results indicate that both profitability and capacity utilization can be improved.

# Hiroaki Ishii, Kwansei Gakuin University, Japan "The airline yield management with early discount setting"

This paper investigates the seat allocation problem in airline, and it is a classic problem in yield and revenue management. By allowing overflow between different demand classes, this paper relaxes the strict assumption in classic literature, i.e. the customers are often strictly segmented. Optimal decisions and profits are derived. The presentation was also focused on the mathematical development of the system.

### Sandra Transchel, Kuehne Logistics University, Germany and Saurabh Bansal: Managing supply risk during the life cycle of technology products

Technology firms such as microprocessor manufacturers often face the problem of random yield in production. With the same production process and materials, the products can vary with different qualities. When supply of specified quality cannot meet demand, substitution is often applied. This paper investigates the optimal substitution policies with different conditions. The result shows that the downwards substitution may not always be an optimal, but on the other hand it is mostly claimed as a manufacturer initiated policy for substitution.



# **Forecasting for Inventories**

#### AUGUST 20, 2012 FORECASTING 1

#### by Aris A. Syntetos

This was the first session of the 'Forecasting for Inventories' stream with a total of three scheduled presentations. All three papers discussed issues related to intermittent demand inventory forecasting and this enabled some continuity and also some interesting remarks to be made. The results presented were also very nicely linked to the keynote paper for the Inventory Forecasting stream delivered by Ruud Teunter earlier on the same day. Ruud talked about 'Forecasting intermittent demand for inventory management' and linking the results presented in the session with Ruud's comments proved to be very interesting. The session was well attended and the presenters received some very constructive comments with regards to their work.

The first presentation was made by Imre Dobos, Corvinus University of Budapest, Hungary (joint work with Andrea Gelei) and it was titled 'Forecasting of products with intermittent demand: a case study from the pharmaceutical industry'. The aim of that work is to analyse the forecasting system of a Hungarian pharmaceutical company. The researchers investigated more than 12,000 products and they were concerned with both demand classification and forecasting related issues for the purpose of setting safety stocks.

The second presentation by **Nikoletta Zampeta-**Legaki (joint work with her colleagues at the National Technical University of Athens, Greece, Fotios Petropoulos and Vassilis Assimakopoulos) was titled 'An alternative implementation of Croston's methodology through a wide range of time series methods'. The researchers introduce an alternative implementation of Croston's approach according to which a wide range of possible methods are considered for the purpose of updating the demand sizes and demand intervals (whereas the original algorithm relies upon Single Exponential Smoothing for both constituent series, i.e. sizes and intervals). A wide range of appropriate accuracy metrics are considered and the preliminary results indicate that there is scope for improving the original Croston's approach.

The final presentation made by **Rob Basten**, University of Twente, The Netherlands (joint work Erwin van Wingerden, Rommert Dekker and Jan-Willem Rustenburg) was titled 'Forecasting demand for slow moving spare parts: a comparative study at three companies'. This work proposes an empirical forecasting method that constitutes an interesting extension of the approach discussed by Porras and Dekker (2008). The researchers also look at the demand characteristics that may influence the empirical performance of various forecasting methods (both parametric and non parametric) and they link their findings to results previously reported in the literature.

#### AUGUST 23, 2012 FORECASTING 2

#### by John Boylan

This was a varied and highly stimulating session, with papers on intermittent demand, seasonal demand and promotional demand forecasting and inventory management.

The first paper "Forecasting in the presence of inventory obsolescence: empirical findings and impact of the smoothing constants", presented by Zied Babai, BEM-Bordeaux Management School, France and co-authored by Aris Syntetos, University of Salford, UK and Ruud Teunter, University of Groningen, The Netherlands was a numerical and empirical investigation of intermittent demand forecasting in the presence of inventory obsolescence. Croston-based methods are not suited to tracking obsolescence because the forecast is not updated after periods with no demand. A variant of Croston's method, proposed by Teunter, Syntetos and Babai (TSB), updates the probability of demand

occurrence after each period and can pick up sudden obsolescence. An empirical investigation of the TSB method showed it be competitive in terms of forecasting accuracy with benchmark methods for items that may be prone to obsolescence.

The second paper "Inventory forecasting: approaches to dealing with seasonality", presented by Aris Syntetos, University of Salford, UK, and co-authored by John Boylan, Buckinghamshire New University, UK, Huijing Chen Mohammadipour, was and Mona an investigation of inventory forecasting for seasonal demand items. The study examined the formation of seasonal groups and the application of group and individual seasonal Mathematical indices. expressions were presented for the Mean Squared Error (MSE) of some seasonal grouping approaches and a heuristic method was introduced to find the aroupings that would minimize MSE. This method also allowed for exceptions, ie items whose seasonal indices would be estimated individually, instead of from the group. An empirical investigation showed that the strategy of employing seasonal groups, whilst allowing for individual exceptions, was a better strategy than applying grouping to all items.

The third paper "Forecasting demand during promotions for perishable items", presented by Karel van Donselaar, Technische Universiteit Eindhoven, The Netherlands and co-authored by Jorde Peters and Ad de Jong, concerned forecasting demand of perishable items during promotions. This is an important issue for Dutch retailers, as these items typically have the highest profit margins and may account for as much as 50% of turnover. However, they are also accountable for the majority of product losses through damage, spoilage or expiration. The researchers examined the effect on sales uplift of a variety of factors, including the level of discounts. They found that discounts of below 30% had little effect on sales uplift. Higher discounts had a greater effect, which accelerated as the discount increased. Nonlinear effects were detected between the explanatory variables and the sales uplift but they did not improve forecast accuracy.

## AUGUST 23, 2012 FORECASTING 3

#### by Karel van Donselaar

In order to find good forecasting techniques and models, a thorough understanding of the demand process is needed. In this session on demand analysis and demand forecasting four scientists presented their current research.

#### John E. Boylan, Buckinghamshire New University, UK "Empirical distribution functions for inventory management"

In the first presentation John Boylan compared three ways to derive an empirical distribution from empirical sales data. Since empirical data not always fit with a theoretical probability distribution function, it may be better to use an empirical distribution function, for example when setting safety stocks or reorder levels in an inventory system.

John explained three alternative approaches to determine the empirical distribution function: non-overlapping blocks, overlapping blocks and bootstrapping. After explaining the (dis)advantages of each method, the results of theoretical and simulation analyses were presented. The results showed how kev parameters like the number of historical observations, the length of the blocks, the underlying distribution and the percentile being estimated affect the estimation performance and the inventories needed.

Mohammad Ali -*Mohammed Zied Babai* -Mona Mohammadpuri - John Boylan - Aris Syntetos: "Analysis of the bullwhip effect in an intermittent demand context"

Although many papers have been published on the so-called bullwhip-effect (amplification of demand variability as orders move upstream in a supply chain), these authors aim to study the bullwhip in a particular environment: the intermittent

demand environment. Assumptions frequently made in the papers on the bullwhip-effect no longer hold in this specific environment. For example the assumption of a ARIMA(p,d,q) model no longer applies. In contrast, the authors assume a different class of demand models: Autoregressive Integer Moving Average (INARMA) models. The first part of their presentation was used to explain their research objectives, methods and to present preliminary results. In the second part of the presentation a discussion was started with the audience on the best ways to continue this research in intermittent environments with demand Constructive comments and suggestions were given by the audience which may help the authors to further analyse and understand the bullwhip effects in this type of environment.

Annastiina Kerkkänen – Janne Huiskonen, Lappeenranta University of Technology, Finland "Linking customer-specific demand information into spare parts inventory management - A case study"

Also the third presentation dealt with an environment in which spare parts are produced and sold. As a result both demand forecasts and ordering rules have to be developed for these items, which are typically slow-moving and intermittent. Rather than using a single rule for all spare parts, the goal of this paper is to find a classification on the basis of past demand data and to link this to the selection of inventory policies. The methodology used in this paper is the participatory single case study. While a first proposed classification was presented, it is interesting to see how this classification would compare to alternative classifications (also based on past research in non-spare parts environments) in terms of classification criteria and performance criteria used as well as in actual difference in performance.

Natalia Szozda, University of Economics in Wroclaw, Poland - Artur Świerczek, University of Economics, Poland "The effect of demand planning process on operational risk in supply chains"

This presentation mainly focused on the entire demand planning process rather than on demand forecasting or the analysis of the demand itself. Especially the effect of the demand planning process on operational risk in supply chains was investigated. For this purpose a survey among 150 manufacturing and trading companies operating in supply chains was conducted. Using Principal Component Analysis the constructs reflecting risk factors and their effects have been identified. Based on the results of the statistical analysis the authors proposed strategies for supply chains to eliminate or reduce the disruptions in a demand planning process.



# Emergency Actions in Inventory Management

# AUGUST 20, 2012 EMERGENCY 1

#### by Dogan Serel

The session consisted of three presentations which were based on mathematical models involving lateral transshipments between stocking points that face uncertain demand. The presenting authors discussed important findings from their work.

The first paper entitled "Negotiated transshipment prices" was presented by Nagihan **Cömez**, Bilkent University, Turkey. The co-authors of the paper are Metin Çakanyıldırım and Kathryn Stecke. The subject of the paper is the negotiations for transshipment price between two retailers selling an identical good. Retailers dynamically negotiate for transshipment prices during a selling period. Transshipment prices resulting from negotiation are determined for various retail power settings. A simple and transparent cost sharing mechanism is proposed to coordinate the retailers' ordering decisions for the case of static and coordinating transshipment price. The paper concludes that negotiated transshipment prices coordinate transshipment decisions.

The second presenter, Fredrik Olsson, Lund University, Sweden presented his paper "Emergency lateral transshipments in inventory systems with positive transshipment leadtimes". The work considers a single echelon continuous review inventory system for spare parts with two parallel locations. There is a deterministic nonzero transshipment leadtime as well as a positive transshipment cost. A transshipment policy based on the timing of all outstanding orders is proposed, and a heuristic model is solved using the theory of nonhomogeneous Poisson processes and partial differential equations. The numerical study shows that the base stock levels determined from the standard lateral transshipment model with negligible transshipment leadtimes may result in a

substantial cost increase if they are applied in a corresponding system with non-zero transshipment leadtimes.

The last paper presented in the session was "Value of information sharing in an inventory system with lateral transshipments", and it is authored by **Benhür Satır**, Cankaya University, Turkey, Secil Savaşaneril and Yasemin Serin. The paper investigates the value of horizontal information sharing in a decentralized service parts management system using a partially observable Markov decision process model. Benhür Satır, the presenting author, discussed how sharing information about their inventory levels influence the service centers' operating policies. The work finds that the value of information sharing may be limited when the cost of requesting a part from the other service center or the cost of rejecting a customer is high. On the other hand, information sharing is valuable when the commission payment is dynamically negotiated upon each part request, and unit profit is low.

# AUGUST 24, 2012 EMERGENCY 2

by Nagihan Çömez

There were three papers presented in this session.

First presentation was made by *Hilal Dag*, Bilkent University, Turkey which titled "**Optimal** assortment planning for retailers using transshipments" that is a joint work with Nagihan Çömez and Alper Şen.

The authors mainly investigate the optimal assortment planning at each of the several retailers managed by a centralized manager. Different than the basic assortment problem studied in the literature, the retailers are allowed to use transshipments among each other when a demanded product is not carried by the visited retailer. The retailer demands are model by exogenous demand model. When the demanded product is not within the assortment of any of the retailers, than one-time demand substitution is considered, where the substituted

product can be satisfied by transshipment as well, if needed. If the substituted demand is not available in any of the retailers, then a second substitution is not considered. Under this scenario, the authors show that when the profit margins for all products are symmetric, then the optimal assortment at retailers can be easily made following an algorithm as it is shown that at optimality both the total assortment and individual assortments at each retailer follow the popular set property, in which products are ranked according to decreasing remand rate. Through extensive numerical analyses, they provide the sensitivity of the optimal assortment according to the change in system parameters. Moreover, they show that when the product demand rates are not symmetric among retailers, then the optimal assortment does not show the well-known popular set property. The study is important to show the effects of commonly used transshipment opportunities among retailers on the assortment decision of the central management.

Next, three studies on disaster management with different research questions were presented. *Peter Kelle*, Louisiana State University, USA presented his work **"What does the public** tolerate? Balancing between cost optimization and worst case scenario in emergency supply", which is a joint work with Helmut Schneider and Yi Huizhi.

This study brings a new performance measure to disaster management problem in a supply chain by combining the well-known expected cost minimization objective with worst-case avoidance. The need for this measure arises because with the expected cost minimization, despite a low probability, there is a possibility of realizing very high cost consequences. On the other hand, focusing on the worst-case scenario, the resulting average cost can be very high compared to the case with the expected cost minimization objective. Thus, the authors introduce a new objective for supply chain disaster management, which they call "p-reliable regret". By selecting the p value of his/her choice, the decision maker focuses on worst case(s), which have a total occurrence rate of at least 100p%. Therefore, only worst cases with considerable occurrence rate are considered for regret minimization. The solution technique introduced is tested on a hurricane model. The model is composed of two stages, which are disaster preparedness and response decision levels. The model is solved under variable disaster scenarios. This study is important to provide a hybrid measure to supply chain disaster management that can smooth out the negative effects both the min-max regret and the expected regret minimization objectives.

The second study on disaster managed was presented by **Nathan Kunz**, University of Neuchâtel, Switzerland titled **"Capabilities investment versus prepositioning inventory: a new approach to disaster preparedness"**, which is a joint work with Gerald Reiner.

This study provides a different perspective on disaster preparedness by suggesting investing in disaster management capabilities instead of investing in prepositioning supplies before the happens. The common disaster disaster preparedness action is deciding where and how much to locate emergency supplies so that these items will be easily accessed during a disaster. However, mainly because of the nondurability of most of the emergency supply items such as food and the high uncertainty in the timing and the location of disasters, prepositioning of goods has a high expected cost. On the other, when the right disaster management capabilities are provided to disaster management organizations such as human resources, knowledge and process management, resources, and community, these capabilities allow the organizations to correctly and quickly distribute the emergency supplies from a central depot. Using a systems dynamics model, authors compare the benefits of investing in supply prepositioning and investing in disaster management capabilities. They consider the distribution of a therapeutic food item during a disaster. Through numerical analyses, they show that when the right disaster management capabilities are present, the distribution of the food from the central depot to demand points can be made as fast as the case where the food items were kept at local warehouses before the disaster. Moreover, lower holding costs are realized when the inventories are not prepositioned. Overall, the study is important to emphasize the significance of providing the right disaster management capabilities relative to common practice of making all investment in supply prepositioning.

The last presentation of the session and the disaster management topic was made by **Yoshiki Matsui**, Yokohama National University, Japan with the title **"The impact of disasters on supply chain inventory management"**.

This study mainly gives an overview of supply chain management and risks of supply chain disruptions. As a response to supply chain disruption risks, the importance of developing agile supply chains is emphasized. A resilient supply chain should have first redundant resources such as diversifying the inventory held to various locations and having multiple supply sources. Second, it is stated that a supply chain should be flexible so that processes can be restructured and procurement strategy can be readjusted when needed. As a road map for a resilient supply chain, it is suggested that constituent activities should be mapped and possible risk sources and critical chains should be pointed on these activities. This would help to make strategic inventory location, supplier selection, and supplier relationship development decisions. The author provides extensive information on Great East Japan Earthquake that took place on March 11, 2011 and disaster management activities taken by important Japanese companies following the earthquake to recover the effects. This study is important to provide a big picture view of supply chain disruptions and the importance of designing agile supply chains.

## AUGUST 24, 2012 EMERGENCY 3

#### by Peter Kelle

The third session of the Emergency Actions in Inventory Management was held on Friday morning as the last session. There were two presentations of two different models for the case when an emergency supplier is available. Both researches contain analytic elements, heuristic solutions and verification through simulation.

Wanrong Ju, Erasmus University Rotterdam, The Netherlands presented a paper "Inventory control with dual-sourcing under yield uncertainty". A Dual-index Order-up-to policy (DOP) is considered which provides a nearoptimal heuristic policy. DOP tracks the inventory position in both sourcing channels. An expedited order is placed to restore the expedited inventory position to its target level and the similarly order-up for the regular inventory position. The major problem is to track the exact inventory positions because of the yield uncertainty. A virtual demand is defined by adding the un-materialized order quantity to the real demand. A Markov chain is used to approximate the sum of virtual demands and the excess of inventory position that provides a good approximation for binomial yield distribution. The performance of the heuristic policy seems to be promising based on a comparison of the optimal policy obtained from the Markov decision model for small instances.

The presenter did a good timing so some questions of the audience could be answered. Questions were related to the extension of varying order-up-to level but it seems that the difficulty is too large to handle it by approximations. Another question was about the yield uncertainty consideration in estimating the regular inventory position. The answer was that only the one-period yield uncertainty is considered there. A debate started about the

possibility of combining the two heuristics based on the two extremes,  $\Delta=1$  and  $\Delta \rightarrow \infty$ . The conclusion was that the combination proved to be inferior.

The second paper of **Dogan Serel** - Nagihan Comez, Bilkent University, Turkey "**Emergency procurement planning in a single-period problem**" was presented by Dr Serel. In a singleperiod inventory problem in some cases an emergency supply source can be used. The authors consider the case when both demand and supply are stochastic. Additionally, they consider a price-sensitive retail demand. Using additive and multiplicative demand models, they explore the sensitivity of the optimal order quantity and price to changes in demand and cost parameters.

After the presentation questions were asked about the convexity and unimodality of the objective function. It turned out that a general proof is not available, the situation is too complex and only for special cases is an analytic proof possible.





# Modelling and Simulation of Multi-Echelon Inventory Systems

# AUGUST 20, 2012 > Multi-Echelon 1

by Hiroaki Ishii

There were three presentations. Simulation model to analyze bullwhip effect under classical and information sharing

"Simulation model to analyze bullwhip effect under classical and information sharing ordering policies" by Ahmed Shaban, University of Rome "La Sapienza", Italy, Francisco Constantino, Guilio Di Gravio and Massimo Troncl They checked bullwhip effect under many ordering polices.

"Introducion of ratios to a simulation model of a closed-loop supply chain with customer-owned stock" by Kirsten Tracht, Michael Mederer and Daniel Schneider, University of Bremen, Germany They discussed spare part repair in place of ordering new one and compared repaired case and ordering new case.

"Consignment stock policy for a two level supply with an imperfect production process with and without restriction interruptions" by Ehab Bazan, Mohmad Y Jaber, Ryerson University, Canada, Simone Zanoni and Lucio Zavanella

The consignment stock policy is discussed in two level supply chain. Results of their research are based on simulation.

# AUGUST 20, 2012 > Multi-Echelon 2

by Sven Axsäter

Christian Howard, *Olle Stenius*, Lund University, Sweden, "Partial or Complete Deliveries in Two-Echelon Divergent Inventory Systems"

Howard and Stenius consider in their paper a standard two-level distribution inventory system with a central warehouse and a number of

retailers. The retailers face independent Poisson demand processes. All sites apply (R, Q) policies. Consider a situation where the central warehouse does not have enough stock for complete delivery of a retailer order but can deliver a partial order. The standard assumption is either to allow only complete orders or alternatively to always deliver partial orders when this is possible. What is new in this a paper is the possibility to choose dynamically between the two alternative policies.

Yong He, Southeast University, China, Houfei Song and Lili Ren, "Pricing and Inventory Decisions in a Dual-Channel Supply Chain with Lateral Transshipment"

The authors consider an inventory model where two channels compete with each other. One channel delivers directly from the manufacturer's e-market place to the customers. The other channel uses retailers for the deliveries. The demand is uncertain. Furthermore it is possible to have lateral transshipments between the channels. There is also a price competition between the channels. Lateral transshipments require that both channels agree on this. The authors have derived a mathematical model to find the optimal strategy.



# **Inventory and the Environment**

# AUGUST 20, 2012 ENVIRONMENT 1

by Maurice Bonney

Hiroaki Fujikawa, E. Xing and Y. Umeda, Tokyo University of Science, Tokyo, Japan "CO<sub>2</sub> reducing VRP algorithm development by ACO"

In the first talk, Hiroaki Fujikawa, presented the paper about a CO<sub>2</sub> reducing VRP algorithm development by ACO. The Japanese government is very concerned about global warming. The speaker quoted that 21.3% of the national CO2 emissions arose from transportation, but despite the Japanese Government wishing that more of their goods should be transported by rail and ship, in many cases this is not practical and near distance travel is mainly by truck. The distance travelled by truck is still increasing and if the country is to attain the Kyoto targets, there is a need to reduce the CO2 emissions created by this form of transport. It was suggested that the CO2 emissions are affected by the loading rate and size of the truck. It was also suggested that there is also the need to reduce the travel distance. The presentation described the development of a vehicle routing program (VRP) and Professor Fujikawa presented a model that examined two aspects of the problem; the transportation cost and the CO2 emission cost, and aimed to make decisions that minimised the sum of the 2 costs.

## Danuta Kisperska-Moron, University of Economics in Katowice, Poland "Inventory management and corporate social responsibility standards in a distribution company"

In the second talk Danuta Kisperska-Moron, suggested that there are two aspects of sustainable supply chain management; the first is to meet the needs of the present without compromising the ability of future generation to meet their needs and secondly, corporate social responsibility, which develops an organisational culture that takes account of economic, environmental and social factors. The whole

presentation was set in the context of selected references and gave a very useful overview of the changing field of integrated inventory management related to supply chain management in a distribution company.

Danijel Kovacic and Marija Bogataj, University of Ljubljana, Ljubljana, Slovenia "Simulating the impact of environmental factors on the extended MRP model"

The third paper presented by Danijel Kovacic described simulation of the Grubbstrom generalised MRP model that also applies to the Supply Chain and reverse logistics. This work is very broadly based, takes account of inputs and outputs, energy use, recycling, taxation, net present value ideas, etc. and uses simulation to examine the effects of individual parameters on the system performance. An impressive overview of a very generalised approach to system design, which promises to be of direct applicability to problems of great interest to the inventory community.

#### AUGUST 21, 2012 ENVIRONMENT 2

by Mohamad Jaber

"Optimal lot sizing for a production recovery system with time varying demand over finite planning horizon" Lakdere Benkherouf, Kuwait University, Kuwait - Konstantina Skouri – Ioannis Konstantaras

The paper is basically a generalised model of that of Konstantaras, Skouri, and Jaber that appeared in Computers & Industrial Engineering in 2010, which considered "studies an inventory system where demand is satisfied by recovered and new purchased items. Used units of a product, returned by (or collected from) customers, are kept in recoverable inventory until the start of a combined process of inspection and recovery. Recovered (remanufactured) items are assumed to be as-good-as new. However, some recovered items do not qualify to be classified as "remanufactured" and are perceived by customers to be of secondary quality. These refurbished items are sold to a secondary market at a reduced price." Paper#1 is different from the work of Konstantaras et al. (2010) by assuming time-varying demand rather than constant demand. The paper is just a mathematical exercise no more no less. It lacks any environmental performance measure of focus. The product return was not considered in an environmental context. I believe this paper was not appropriately assigned to Environment 2.

**"Tactical decision making for designing green logistics Networks"** Ioannis Mallidis, Aristotle University of Thessaloniki, Greece - Rommert Dekker, Econometric Institute, Erasmus University Rotterdam, The Netherlands - Dimitrios Vlachos:

This paper discussed a case of dual sourcing, one in Greece and one in China. The paper attempts at comparing alternative supply chain networks and inventory policies by studying optimal cost and environmental performance (CO2 emissions). The methodology and costing analytical approach was questionable and the presenter was not able to convince or answer to the audience questions. The presentation was a complete chaos with no cohesive flow. The contribution of the paper was not clear. I do not recommend this paper for the Special Issue.

#### "Optimal two-stage ordering policy with information update and carbon emission" Katja Rettke, Friedrich Schiller University, Germany

This paper first developed a Single-period dual sourcing model based on the newsvendor problem, then a two-stage newsvendor model with emissions trading for transport. The sourcing types are domestic and off-shore. It assumes that the demand for the product is deterministic from the domestic source and stochastic (because of lead-time) where ordering starts before the start of the selling season. The problem seems to consider a real case problem from the music industry where retailer offers a CD album of a certain musician: "(1) sale of a CD single of the same musician before the start of the selling season of the album, (2) especially before the second order opportunity, (3) observing actual demand for the single, (4) updating of the

demand forecast of the album by observing the market signal (market signal: observed demand for the CD single), and (5) market signal is an indication of the future sales of the full CD album and is used to update the demand forecast of the album". The paper presents an elegant mathematical problem." The paper found that "when the onshore source is used to fulfil demand, leftover inventory is possible (because demand is uncertain at this point of time as well)", " the optimal order quantity depends on the parameters of the posterior predictive distribution of the demand X (mean and variance) and therefore it also depends on the observed market signal r", "incorporation of an emission trading scheme for transport that has to be considered when ordering from the offshore source", "the model can provide decision support for companies on how much to order from a certain source when environmental regulations for transport based on the EU ETS have to be considered"

The model is similar to "The economic and environmental performance of dual sourcing" paper that was presented at the 16th ISIR. A major difference is that paper#3 considers updating the demand based on available information. I recommend that this paper be considered for the Special Issue. I expect the reviewers to be critical (perhaps major revision).

# AUGUST 23, 2012 ENVIRONMENT 3

#### by Mehmood Khan

The first one was an analytical model while the second one was a simulation model. Both presented a nice addition to the area of inventory modeling with environmental concerns.

There were only a few people in these presentations. Each presentation was finished in the allocated time. Both presentations were followed by couple of interesting questions on implications and assumptions of their work. "A Joint Economic Lot Size Model with Carbon Footprint" Mária Csutora, Imre Dobos and Gyöngyi Vörösmarty, Corvinus University of Budapest, Hungary

In this paper, they presented an analytical EOQ model to incorporate carbon footprint. They discussed

- Literature related to the joint economic lot sizing problem
- The importance of reducing carbon dioxide in supply chains
- Incorporation of carbon policies in joint economic lot sizing problem
- Their schematic of the model
- The analytical model
- Conclusions

"Impact of transportation lead-time variability on the economic and environmental performance of inventory systems" Jörg M. Ries, Darmstadt University of Technology, Germany, Johannes Fichtinger and Emel Arikan

In this paper, they studied the impact of the variation in lead time on environmental performance of an inventory system. They discussed

- Literature related to the problem and their motive behind the study
- Their simulation model for two level supply chain
- The decision flow chart and parameters for the simulation model
- The impact of CO2 emissions and lead time on their model
- Analysis of the lead time variation and transportation cost on their model
- Conclusions

#### AUGUST 24, 2012 ENVIRONMENT 4

#### by Gyula Vastag

The three papers of the session were, to a varying degree, in the literature review and problem formulation phases; there were ideas presented about how the authors planned to proceed but no final results were revealed.

The first paper Imre Dobos - **Gyöngyi Vörösmarty** - Mária Csutora, Corvinus University of Budapest, Hungary, "**Sustainable supplier selection and evaluation using DEA-type composite indicators**", presented by Gyöngyi Vörösmarty, argued for using DEA type composite indicators. The authors narrowed down the supplier selection problem to a choice between scoring models. The authors, using a somewhat simplistic example, aimed to highlight the role of supply chain and green factors and to develop a selection model fitting the externally given expectations.

**Mehmood Khan** was the second speaker (Mehmood Khan, Abu Dhabi University, United Arad Emirates - Mohamad Y. Jaber, Ryerson University, Canada - Christoph H. Glock, Technische Universität Darmstadt, Germany) "Impact of learning on the environmental performance of a two level supply chain" who cut his intriguing presentation short perhaps with the intention to give the necessary stimulus to the audience to ask more questions. The main trust of the paper was to introduce (and measure) the notion of quality improvement in a model of a two-stage supply chain.

The final presenter was **Arjaree Saengsathien** (Arjaree Saengsathien, University of Exeter, UK -David Z. Zhang: **"An inventory and sourcing decisions model with a temporary price discount for improved sustainability in food supply chains"**). The paper was about developing a model that determines inventory and sourcing decisions in a food chain, with the goal of minimizing total cost invested, wastes from unqualified items and carbon emissions generated together with a consideration on the effect of price markdown.

The session was attended by 8-12 people; some of them stayed throughout the session, others came to see specific presentations. Overall, the authors were given excellent feedback to build on and improve their paper.

# **Service Logistics**

#### AUGUST 20, 2012 SERVICE 1

by Kalevi Kylaheiko

Ahmad Al Hanbali – van der Heijden, University of Twente, The Netherlands "Interval availability analysis of a two echelon, multi-item system"

In this paper (that a bit surprisingly cannot be found in the proceedings) the authors extended the traditional multi echelon model by introducing the constraints that relate to the multi-item system. Without any proceedings and based only on listening to the presentation it is hard to say whether it contributed anything new into the very extensive literature about multiechelon systems. The presentation as such was clear and raised some interesting questions concerning the generalizability of the model.

Marco Bijvank, Erasmus University, The Netherlands – I.F.A Vis – J. Boter "Investment decisions in collections for rental companies under customer choice behavior"

In this very interesting paper the authors analyzed the performance level of customer service (measured by availability and accessibility) focusing on public library services. The public libraries have to balance a highly varied assortment with the risk of customers not getting the exact title they wanted to have. If that is the case the customer can take another closely related title, go to another library, make a reservation or go away with empty hands. The main idea of this clear paper was to look at the returning times of the titles borrowed. By means of this data the authors managed to build a stochastic customer choice model where a probability is assigned to each alternative in case of a stock out. By assuming that the customers arrive according to the Poisson process, the system can be approximated by a quieting network with no buffers. They also suggested that a similar model could be usable in case of spare parts inventory problems. In an interesting case study the authors demonstrated that their

heuristic procedure really is effective and manages to find a collection with an average item fill rate of 55% compared to normal 30 %. The presentation was very clear and illustrative and raised many questions. It would have been interesting to hear a bit more about the other applications of the model, however.

Eric H. Grosse – Rafael Ballester - Ripoll – **Christoph** H. Glock, Technische Universität Darmstadt, Germany **"A Simulated annealing approach for** capacitated order picker routing in a warehouse"

In this presentation Professor Clock introduced a simulation model to analyze the order batching and routing problem of order pickers in conventional multiparallel-aisle picker -to-part order picking systems. Since manual order picking is costly and time consuming it is advisable to try to minimize the travel time and distance of the picker in the warehouses. The authors launched a simulation model that allowed to present several heuristics that really can shorten (or even minimize) the travelling costs within a warehouse. Finally, the heuristics generated was compared and evaluated in a very extensive numerical study. The authors managed to show (even if it was hard to follow in the presentation given) that the developed heuristics really provided a solution for improving order batching and order picking efficiency.

The presentation was clear but not quite balanced, the basic heuristics was introduced very rapidly and the numerical study was quite too extensive to follow within the time limits given.



#### AUGUST 21, 2012 > SERVICE 2

by Alan Stenger

#### "Joint Optimization of Maintenance and Spare Components: The Value of Plannability"

Farid Mardin, Taoying Farenhorst-Yuan and **Rommert Dekker**, Erasmus University Rotterdam, Econometric Institute, Rotterdam, The Netherlands

This paper deals with strategies for replacing components in complex systems when a preventive maintenance approach is used to keep the system operating. In preventive maintenance, we periodically shut the system down and replace components as needed. There are three basic strategies for deciding which components to replace:

- 1. Age Replacement: replace any component that has reached its "critical" age
- 2. Block Replacement: Replace all components at prescribed times
- Modified Block Replacement: Replace only those components whose age is greater than some threshold

Age replacement has been shown to be superior to block replacement (Berg, 1976), but this conclusion did not take into account the consequences of this strategy for the resulting spare components supply chain. In age-based replacement, items are replaced at a wide range of times. In block replenishment, it is much easier to achieve a joint replenishment time and coordination with the ordering of spare components.

The problem addressed in this paper is to determine under what conditions the joint optimization of maintenance and spare components control will be best under block replacement type strategies.

The authors investigated the problem by considering n identical components, each with a Weibull distributed lifetime distribution, and for which both the costs of failure and of preventive replacement are given. There is also a spare parts inventory holding cost. The replacement

policy states when components should be replaced (when enough spare parts are available). If these are not available, then an emergency order is placed at a premium cost, and the component is replaced when it becomes available. Upon failure, a component is replaced if a spare is available, otherwise downtime is charged per unit time. All three strategies, as well as some additional hybridstrategies, were tested using simulation.

The results confirm that age replacement is superior when only maintenance costs are considered. On the other hand, when ordering and inventory costs are included the modified block strategy is superior. However the results are very parameter-specific. Joint optimization clearly makes sense, but often maintenance and spare parts management are in separate organizations that see no advantage for their organization for doing this.

### "Optimal Control Policy for Spare Part Inventory in Existence of Supply Risk and Secondary Market" *Mustafa Hekimoglu*, Rommert Dekker and Taoying Farenhorst-Yuan

Erasmus University Rotterdam, Econometric Institute, Rotterdam, The Netherlands

This presentation reports on research in progress on a special situation in the management of spare parts. This situation involves spare parts for equipment that is no longer produced, but the installed base has a fairly long life expectancy assuming parts can be found to support it. However due to several factors such as low profitability of the part, technological obsolescence, etc., support is subject to the risk of supply failure. That is, from the maintenance company perspective, the supply of certain spare parts may stop while demand continues for maintenance services and parts. In some sectors secondary markets may exist for spare parts trading among different parties. Existence of such a supply alternative makes the inventory control system more complex. On the other hand too much reliance on the secondary market may encourage the regular supplier to stop producing the part.

The objective of the research is to build a recursive inventory control model for a system including supply failure risk and a secondary market. The researchers have an empirical data set of 248 part numbers, of which 60 are at risk. Regression analysis of this data shows that the part price and the lead time are positively correlated with rising risk of a part going out of production. A Markov model is under development, and will incorporate nonstationary, random lead times; non-stationary, random prices; and non-stationary, random probability of going out of production. The researchers have proven the conditions under which the Markov model can go to a single stage model, and that this reduced model is convex, among others.

# "Last Time to Buy and Reuse of Spare Parts for Advanced Capital Goods"

**Sina Behfard**, Mathieu van der Heijden, Ahmad Al Hanbali and Henk Zijm

University of Twente, School of Management and Governance, Enshede, The Netherlands

Complex capital equipment, such as computer or medical systems, generally requires high levels of uptime. When parts fail, they are replaced from a spare parts inventory, making inventory availability a critical issue. That inventory can be replenished by the purchase of new parts or the repair of the failed parts that have been replaced and returned. Eventually the case may arise that the supplier of the new parts will no longer make those parts, and there will be a last time to buy (LTB).

This research seeks to find an approach to determine the optimal LTB order in combination with an optimal repair policy for items returned from the field. The approach balances the various cost factors, such as holding, repair, shortage during the service period, and obsolescence cost at the end of the period. Lead times are variable for both the return of parts from the field and the repair times. Furthermore, only a fraction of the defective parts will be returned, and only a fraction of the repairs are successful. An exact model is developed for a single item and a single stock point. The model considers a multi-period problem with discrete time intervals (an application of Stochastic Dynamic authors Programming). The assume an exogenous, non-stationary, independent demand pattern; a pull policy for repairing items (when inventory position is running low); and uncertainty in the number of failed items that are suitable for repair. The repair lead time is deterministic and the return lead time is negligible.

For the solution, the researchers use the exact method for small problem instances to be used as the benchmark for the approximation method -- e.g. low demand (slow movers) and deterministic repair lead time (zero or one period) or stochastic lead time with exponential distribution. For large problems, they use an approximation method that assumes deterministic repair lead times. In general, the approximate solution is less than 1 percent away from the exact solution.

Numerical tests are used to study the sensitivity of the solutions to changes in the key parameters such as repair lead time, repair return yield, return lead time and return yield. As yield increases from returns, the LTB goes down dramatically. As repair costs increase, or shortage costs increase, LTB goes up, but at a relatively slow rate.

Future model refinements include: two echelon models, repair yield, scrap policy, and other reuse options. Another possibility is to incorporate a demand life cycle forecast as input for the LTB quantity model.

# AUGUST 21, 2012 > SERVICE 3

#### by Danuta Kisperska-Moron

First paper has been prepared by Petra Pekkanen, Antti Martikainen and **Petri Niemi** (Lappenranta University of Technology in Finland): "**Developing a service offering for a logistic al service provider – case local food supply chain**" It was based on an EU sponsored project and its objectives were twofold: 1) to identify business models and service offerings for a logistics service provider in local supply chain, 2) to conclude and suggest on the process of creating new business models in logistics services. The authors classified the existing local service requirements of different participants in the regional food supply chain analyzed in the light of current knowledge about logistical service offerings. The paper examines two potential service offerings: focused service offerings for food producers and full service offering for deliveries to customers, including core, support and additional services. The set of two service offerings have been also evaluated from the point of view of different stakeholders in the local food supply chain.

Second paper **Guangyuan Yang** from Erasmus School of Economics in the Netherlands **"Risk pooling in service logistics"**.

The main goal of the paper was 1) to develop a consistent and coherent risk measure based on empirical data, and 2) to provide a practical risk mitigation strategy for supporting postproduction capital goods. The cost of repairs can be reduced in post-production capital goods supply chains by procurement from the secondary market. In reactive business processes, the time pressure and price uncertainties limit the possibilities of expensive repairs. In order to evaluate the risks of the extreme repair costs for critical components used to support continuous operations of aircrafts. In the process of development of risk measure the concept of Conditional Value-at-Risk (CVaR) was used. In the process of analysis the Expected Extreme Repair Cost (i.e. CVaR) in the tail beyond the cost trigger point was calculated. On that basis the proactive procurement strategy was proposed. Moreover, the results of verified the study were by practical implementation of the results at Fokker Services B.V. where significant costs saving were achieved.

Both papers resulted in an interesting professional discussion. The audience discussed the theoretical basis of research, used research methodology and techniques, and achieved practical results. The presenters indicated also

some limitation of their research and suggested future directions of their investigation.

#### AUGUST 21, 2012 > SERVICE 4

by Gudrun Kiesmüller

**Maarten Driessen**, Eindhoven University of Technology, The Netherlands – W.D. Rustenburg – G.J. van Houtum – V.C.S. Wiers

# "An empirical study on repair shop control in maintance spare part environments"

This paper presents the specific control characteristics of repair shops in maintenance spare parts environments. The physical layout of repair shops has many similarities with traditional job shops, however, empirical evidence shows that the required control of repair shops is different on several characteristics. In-depth case studies are carried out at six different companies that maintain high value capital assets that they need to deliver their products and services. It is concluded that to approach repair shop control in maintenance spare parts environments, a dedicated framework is necessary. The control characteristics as described in this paper will be part of this framework.

# "Spare parts sharing with joint optimization of maintenance and inventory policies"

**Christian Larsen** - Lars Relund Nielsen - Hartanto Wong, Aarhus University, Dept. of Economics, CORAL, Denmark

We consider an industrial setting in which a number of companies operating the same technical system are willing to share expensive spare parts that are required for both failure replacement and preventive maintenance purposes. The novelty offered by our study lies in the integration of maintenance and inventory policies that takes place in a collaborative setting where spare parts are shared by different companies. To the best of our knowledge, the literature to date only tackles all those aspects partially. The specific setting considered in this study consists of one 'holding' company and a number of 'participating' companies. The inventory of spare parts are pooled at the holding company who is responsible for controlling spare parts inventory in the system whereas the participating companies are given access to use the spare parts whenever a preventive maintenance or failure replacement occurs. We develop two models to analyze the problem. The first model deals with the joint optimization of maintenance and spare parts inventory policies under a centralized setting in which all decisions are made by a central decision maker. We develop a discrete-time Markov decision process formulation for both a single-company problem and a multi-company problem. The model developed is general in the sense that no restrictions have been made in relation to the choice of inventory and maintenance policies. The cost savings obtained as a result of sharing the spare parts are evaluated through numerical experiments. In the second model, the cooperating companies are considered as independent entities. Using a cooperative game framework, we propose a number of cost allocation schemes such that all the companies involved are better off by sharing the spare parts rather than actina independently.

## "Improving service parts inventory management for technological products. A simulation-based case study"

Francesca Plebani, Nicola Saccani, Andrea Bacchetti, University of Brescia, Department of Mechanical and Industrial Engineering

The increasing importance of after sale services and service parts provision generated increased attention by OEMs that need supporting the products they sell. An efficient and effective service parts management is, indeed, a lever for improving customer satisfaction and profits. Inventory management plays a central role in achieving these goals. However, previous research suggested that the real-life application optimization models and techniques of developed by scientific literature is limited. Therefore, this paper considers and models a problem, real-life and proposes α simulationbased solution understandable and

practically implementable by company managers. We consider the case of a multi-item, two-echelon inventory system for service parts that consists of a central warehouse and a number of local warehouses. The local warehouses consist of the vans of field engineers, and are therefore subject to space constraints. The case study concerns a company that manufactures printing systems. A regional warehouse located in Italy serves about 180 vans of field engineers located all over the country. The OEM centrally manages the stock allocation and dimensioning for all the local warehouses. An (s, S) policy is adopted, with re-order points and order-up-to level set by the analysis of historical consumption and experience. Both normal and emergency orders are allowed. We aim to assess by the means of a simulation model the opportunity to reduce logistics costs without affecting the service level, considered satisfactory by the company.

Therefore, different strategies are tested and combined:

i.) modifying the set of parts to be allocated to the vans;

ii.) increasing order-up-to levels of "fast movers" to reduce the number of shipments;

iii.) reducing the delivery frequency and constraining the number of emergency orders.

The scenario analysis carried out suggested easily achievable improvements to the company, and provides as well conceptual insights for service parts management. Finally, since in the simulation we adopted a single-echelon perspective (the costs at the regional warehouse are incurred by the parent company of the case company studied) we propose further developments based on a global perspective (two-echelon, information sharing and adoption of an integrated perspective at the horizontal level).

## AUGUST 21, 2012 SERVICE 5

#### by Refik Güllü

The first paper in this session, "Last time buy decisions for products sold under warranty", was presented by *Matthieu van der Heijden*, University of Twente, The Netherlands (co-authored with Bermawi P. Iskandar). In this talk van der Heijden argued that the last time buy decision, different from other studies in this area, is a decision problem that needs to be addressed in a multiproduct setting, and therefore the resulting optimization problem is much more complicated. He presented exact and approximate analysis for the joint problem of finding the last time buy quantity and the warranty servicing strategy (to repair or to replace).

The second paper, titled **"Spare parts inventory control for an aircraft component repair shop"**, is presented by Willem van Jaarsveld, Erasmus University Rotterdam, The Netherlands (coauthored with Twan Dollevoet and Rommert Dekker). Willem van Jaarsveld's presentation focused on efficient optimization of the policy parameters of an (s,S) policy for the spare parts. As the resulting optimization model involves integer decision variables, van Jaarsveld's approach uses a column generation based algorithm and utilizes various analytical properties of the problem together to obtain a fast and efficient solution.

The last paper of the session, "A joint optimization problem of preventive maintenance intervals and spare parts inventory for multi-unit systems" was presented by Young Jin Han, Pusan National University, South Korea (co-authored with Won Young Yun). In this work a model that aims to optimize jointly the preventive maintenance intervals for a train network, and the policy parameters for spare parts inventory system operating under (s,S) policy is considered. Young Jin Han presented a numerical study based on a metaheuristic algorithm.

#### AUGUST 23, 2012 ► **SERVICE 6**

by Marko Bijvank

All presenters where present on time and put their presentations on the laptop. Furthermore, all three speakers stayed within their 30 minutes and kept to the format of a 25 minutes presentation and 5 minutes for questions. There were about 30 people attending this session. As a result, it was possible to have a short discussion after each presentation.

#### "Optimal and heuristic repairable stocking and expediting policies in a fluctuating demand environment"

Joachim Arts, Eindhoven University of Technology, The Netherlands (in collaboration with Rob Basten and Geert-Jan van Houtum) The topic for this presentation is a maintenance system, which fits very well in the Service Logistics theme for this session. In particular, they consider a system with advanced demand information for repairable items that can get repaired based on two different modes (either performed by the repair shop itself or expedited). All relevant aspects are discussed: the structure of the optimal policy, and a heuristic policy. This heuristic policy results in almost optimal costs, with an average optimality gap of 0.2% on average (with a maximum gap less than 1%). There were quite a number of questions about the assumptions made in this presentation.

# "An improved decision rule for emergency replenishments"

Sven Axsäter, Lund University, Sweden

In this presentation, a single-stage inventory system with compound Poisson demand and complete backordering is studied. The inventory is replenished by a continuous review (R,Q) policy, but it is also possible to get so-called emergency replenishments. The question is how different types of orders can be combined in an efficient way. This has already been studied in a paper by Sven Axsäter (the presenter) in 2007. However, in this presentation a new decision rule is proposed in which an extra delay is incorporated. This new rule results in 13% cost savings compared to the old decision rule.

# "Joint pricing and inventory decisions with delay sensitive customers"

Refik Güllü, Bogazici University, Turkey (in collaboration with M. Guray Guler, Taner Bilgic) The final presentation in this session is about a service system with multiple customer classes. The service system uses a base-stock policy. Each customer class corresponds to a certain lead time and the system has to decide on the price to be charged for each class. Based on these prices, the customers decide whether they are willing to pay the price based on the price itself and the waiting time (or waiting cost). Since there are a lot of decisions to take in this setting, it was sometimes difficult to fully understand the details, but the concepts were explained very well. Despite these technical details, the presenter was able to illustrate how to make the order-up-to decisions as well as the pricing decisions.

# AUGUST 24, 2012 SERVICE 7

by Matthieu van der Heijden

Within the large stream of service logistics, the seventh and last session contained three interesting presentations on spare part inventory management from different perspectives.

The first presentation by **Elisa Alvarez**, University of Twente, The Netherlands "Service differentiation through selective lateral transshipments" (University of Twente, the Netherlands) focused on service differentiation for performance-based service contract fulfillment. A common approach in literature is the use of so-called critical level policies, where stock is reserved for premium customers once the inventory level drops below a certain threshold. Such policies tend to have practical drawbacks, such as a lack of acceptance from both customers with regular contracts and employees who handle spare parts requests. As an alternative, Elisa proposes the use of selective lateral transshipments

focused on waiting time reduction for premium customers. That is, warehouse stock is used to meet demands from all types of customers. However, if a warehouse does not have parts in stock, it can meet demands from premium customers by using stock at other warehouses at the same echelon level (i.e. a lateral transshipment). As transshipments are relatively expensive, this option is not used for nonpremium customers. This is translated in a multiitem model with two customer classes and multiple warehouses, with the objective to minimize system costs while meeting the customer-specific service requirements at each warehouse. Extensive numerical experiment shows the added value of using selective transshipments by comparing it to alternative approaches, such as one-size-fits-all approaches and critical level policies.

Next, Frank Karsten (Eindhoven University of technology, The Netherlands) discussed the question how to share the benefits from risk pooling of spare part inventories over multiple organizational units. He considers a setting with several companies who require expensive, lowdemand spare parts for their high-tech machines. They can collaborate by fully pooling their inventories of common parts, which is beneficial from the whole system's point of view. The question is how the participants should distribute among themselves the collective costs of the shared inventory system in a fair way. Using structural properties, he proves that if total costs are allocated proportional to player's individual demand rates, then no subset of players has an incentive to split off and form a separate pooling group. That is, this proportional rule always accomplishes core allocations of an associated cooperative game. Also, he showed that if this proportional allocation is implemented via a certain intuitive process of allocating realized costs as they materialize, then players are induced to truthfully reveal their private demand information a priori.

In the third and last presentation, Guangyuan Erasmus University Rotterdam, Yana The Netherlands, discussed risk management in performance based logistics. Under Performance Based Logistics (PBL) contract, an original manufacturer (OEM) equipment or an independent service provider is required to meet contractual life-cycle product support levels regardless of the cost of doing so. Inspired by a case study at Fokker Services, Guangyang developed a consistent and coherent risk measure based on empirical data., and provided a practical risk mitigation strategy for supporting post-production capital goods. In a closed-loop supply chain of post-production capital goods with performance based contracts, OEMs or service providers are committed to provide spare parts for continued operations by component repair or procurement from secondary market. To evaluate the risks of the extreme repair costs for each critical component, he developed a consistent and coherent risk measure using the concept of Conditional Value-at-Risk (CVaR). In the postproduction capital goods supply chain, one can try to avoid the extreme expensive repairs by procurement from the secondary market with lower prices. However, in reactive business processes, due to the time pressure in the makeor-buy decision making and high uncertainties in the market prices, these expensive repairs can hardly be avoided. To mitigate the risks in extreme repair costs, a proactive procurement strategy with purchasing limits (both prices and quantities) is proposed. These results have been applied in a case study at Fokker Services B.V., a performance-based aircraft maintenance, repair and overhaul (MRO) service provider. The risk evaluation of repair costs and the proactive procurement strategy enables the MRO service provider to make more consistent make-or-buy decisions and to plan proactively for the risk mitigation. As a result, large cost savings have been achieved.

Moments of the banquet evening



Attila Chikán and Lou Maccini welcome the participants.



ISIR was founded 30 years ago, some of the founding fathers are still with us in 2012.



Bob Grubbström remembers of the first symposium.