
# Session chairs' report

The dates for the next ISIR Symposium are **August 20-24, 2012**

**AUGUST 23, 2010**

## Opening Plenary Session

by Henk Zijm

On Monday morning, August 23 (2010), the conference started with some welcoming words by the First Vice-President and Secretary General, prof. Attila Chikán, followed by three lectures by Henk Zijm, Louis Maccini and Jacob Wijngaard.

**Inventory Research: Challenges posed by a changing world**

*Henk Zijm,* University of Twente, the Netherlands (ISIR president)

In his opening address, Henk Zijm addressed some major societal changes and challenges that certainly require attention from supply chain researchers and inventory management specialists. In particular, he discussed possible contributions from our field to energy management and environmental problems, addressing design and management issues of alternative energy supply chains such as biomass production and a reduction of the water footprint in many everyday's consumer product chains. Also, the topic of winning back materials from disposed products was discussed, through reverse logistics in closed loop supply chains, and ultimately the use of more bio-degradable materials through cradle-to-cradle design principles. A key idea is that returned products represent a value stream, not just a waste stream, while furthermore it becomes key to address the real costs of waste, pollution, etc. This is typically a field where all sections of ISIR may contribute. He also revealed a national plan of action in the Netherlands to strengthen its logistic position while at the same time diminishing the ecological footprint, and finally made a plea to also pay attention to humanitarian relief operations, of which he briefly outlined a number of basic infrastructural and communication/ information problems, which present key differences with classical supply chains.

**Inventories, Monetary Policy, and the Market for New Automobiles**

*Louis Maccini,* Johns Hopkins University, United States (ISIR president-elect)

In his presentation, Lou Maccini addressed the effects of monetary policy on the market for new automobiles.

A representative automobile firm is modelled as a dynamic profit-maximizer who is a monopolistic competitor and holds large quantities of inventories in order to facilitate sales. The model of the firm is used to develop a market-equilibrium model that determines the price and quantity of new cars and light trucks. The market-equilibrium model is estimated using quarterly micro-level data on new cars and light trucks. An important issue discussed was the question on how interest rates change as a result of monetary policy. Increases in interest rates dampen sales through two channels. First, higher interest rates raise the cost to the firm of holding inventories; as the firm economizes on its inventory holdings, consumer find it more difficult to be matched with their preferred vehicle and fewer sales are consummated. Second, higher interest rates raise the cost to consumers of purchasing a new vehicle on credit. We find both channels to be quantitatively important. One may also wonder how differences in sales in various countries may be attributed to different monetary policies (he minor appearance of SUV's in e.g. Dutch cities is partly due to the far higher fuel prices, due to stringent taxes, but also to high environmental concerns of city authorities).

**On the optimality of (s,S) inventory policies in case of a constrained production capacity**

*Jacob Wijngaard,* University of Groningen, the Netherlands (former ISIR president)

Jacob Wijngaard started his presentation with the remark that, contrary to the previous two speakers, he was not going to address challenging world problems, having learned that many smaller, classical inventory problems pose already large difficulties. The periodic single-product inventory replenishment problem with independent identically distributed demand, backlogging and set-up cost is a classical problem in stochastic operations research. It seems so obvious that the optimal policy should be of the (s,*S*) type, certainly in the presence of set-up costs. In the same spirit, one expect a similar result to hold in the cases of limited production capacity per period, i.e. once the inventory drops below a certain threshold value (s), produce up to *S* again, *or as much as possible*. This however is not true.

For the continuous version of the problem however, the speaker presented highly interesting results. The capacity constraint is modelled as a *production rate*, rather than the *production amount per review period*. Orders arrive according to a Poisson process and the i.i.d. demands follow some arbitrary distribution. The inventory is replenished at a constant rate when the production is on. Then again the average optimal policy proves to be of the (s, *S*)-type: as soon as the inventory gets below s, production is switched on, as soon as the inventory hits *S*, the production is switched off.

## Second Plenary Session

by Clay Whybark

**The Effects of Integrating Human Judgment into Forecasting and Stock Control Decisions**
*John Boylan,* Buckinghamshire Chilterns University Collage and *Aris Syntetos,* University of Salford, United Kingdom

John Boylan presented this paper, the first in the academic literature to report on what happens to forecast accuracy and stock control results when managers adjust statistical forecasts based on their experience and knowledge. The large empirical dataset used for this research was provided by a pharmaceutical company. Information relevant to the fast and intermittent demand items was extracted from the dataset for the analysis. The authors compiled information on forecast accuracy, using standard statistical measures and evaluated stock control performance with inventory and service levels. In related work, they investigated the adjustment of replenishment quantities directly as opposed to through the forecasts. This provides a base for further research into the relationship between human judgment, forecasts and inventories.

**A Multi-echelon Inventory Control Model for Implementation in Practice: The Case of a Global Spare Parts Provider**
*Johan Marklund and Peter Berling,* Lund University, Sweden

Johan Marklund presented the paper in which the authors (in cooperation with a software provider) develop a procedure for setting reorder points for different customers of a single supplier. The model extends the work of J. Andersson and several others and, by using an imputed backorder cost, provides a model that decentralizes the system while simultaneously meeting a series of practical requirements. Among the requirements are that the procedure meet target service levels for customers, accommodate various demand distributions, meet direct demands on the warehouse and be understood by end users. Numerical tests show that the model performs well relative to other methods and is closer to service level targets at lower levels of inventory when tested with actual data. The software company is determining how to incorporate the model into their system.

**Measuring Supply Chain Cost**
*Annette Pattersson and Anders Segerstedt,* Lulea University of Technology, Sweden

Anders Segerstedt presented this paper which reports the results of interviews with 30 companies in 10 different industries about measuring supply chain performance. The survey discloses that the companies use a variety of measures for both cost and performance and that they have quite different views as to what constitutes supply chain excellence. The measurement of cost is critical to cost control and to determining the contribution of supply chain performance to profits. There were many methods for measuring cost, one of which uses standard costs as the basis with percentage changes applied as conditions warranted. The interviews suggested an actual cost based model would be more accurate. Both the standard and actual cost approaches were applied to an actual case. An analysis of the results confirmed that there were substantial cost differences between the two approaches. Sometimes, however, people don't want to know how bad the situation is and one solution to any bad news is to shoot the messenger.

# Economics of Inventories

## AUGUST 24, 2010 ▸ EC1

by Michael McMahon

There were three papers presented in this session.

*Kalevi Kyläheiko* presented his work "**Explaining the shifts in inventory behavior in the Finnish manufacturing sector during the period 1980-2009**" which is joint with Heli Virta and Maija Hujala.

This work aims to examine the time trend of the inventory to turnover ratio in the Finnish manufacturing sector (as a whole, and for ICT, and paper and pulp individually). The authors try to identify the role of three different hypotheses (all derived from the Arrowian inventory holding motives) to explain any structural breaks in the series.
They find that there are different drivers of inventory behavior in different industries at different times. Focusing on the two sub-industries, the changes in inventory to turnover ratio reflect a buffer motive during economic downturns, and though present in both sectors, the decline in inventory to turnover ratio as a result of globalization and modern inventory management techniques was stronger in ICT industry. Finally, the idea of inventory speculation motives appeared to be important only in the ICT sector.

Next, *Zsolt Matyusz* presented joint work with *Attila Chikán and Erzsébet Kovács*; the presentation was entitled "**Inventories and national competitiveness**".

In the work the authors ask whether there is a relationship between the inventory behaviour of countries and their competitiveness. Using OECD data, as well as two different measures of competitiveness (those from IMD and the World Economic Forum), they find significant correlations between inventory changes (as a % of GVA) and the competitiveness indices. Moreover, inventory changes are closely correlated with the other measures of macroeconomic efficiency.

These correlation results are then complemented with multidimensional scaling, cluster analysis, and factor analysis. This allows countries to be grouped into different broad levels of levels of competitiveness. This work therefore represents a first step in what the authors hope will be a new way to think about the issue of the role of inventories in the macroeconomy.

Finally, *Adel Ghobbar* presented a paper entitled "**The Evaluation of Cannibalization and Components Commonality on Inventory Total Cost: Predictive Model for intermittent demand on Aircraft Maintenance**". Though not directly related to the economic study of inventories, this paper provided the audience with a excellent review of some work for the Fokker aircraft company to develop a predictive cost model for cannibalization of aircraft parts which aimed, among other things, to reduce lead-times, costs.
Cannibalization, as was explained on the day, involves the removal of serviceable parts from an aircraft/component for use in the repair of other equipment of the same kind. It is a standard maintenance technique, but still viewed as a last resort. This work provided a detailed overview of the issues that arise in the decision to take up this last resort and the development of a quick and easy model to help maintenance workers make a decision as to whether a part should be cannibalized.

## AUGUST 26, 2010 ▸ EC2

by Louis J. Maccini

Three papers were presented:
**"Inventories in Motion: A New Approach to Inventories over the Business Cycle"** by *Michael McMahon* of the University of Warwick, Department of Economics, United Kingdom.

The author examined those inventories which arose naturally in the gaps between the production of goods and their consumption (distribution inventories) as well as a simple storage motive. Though these are technically difficult to embed in a general equilibrium business cycle model, he overcame these difficulties using a non-linear solution algorithm. Simulating a monthly model, the data were aggregated to a quarterly frequency and found that the inventories model matched the aggregate data well. Then it was considered whether changes in the management of inventories by firms in the last 25 years, such as the so-called "Walmart Approach", may have caused the coincident decline in the volatility of GDP growth – the Great Moderation. Mapping the salient features of the improvements in inventory management, such as cheaper and faster distribution of goods, into the parameters of my model, little role was found for improved inventory management in explaining the decline in macroeconomic volatility. While the inventory management changes were useful to match aspects of the changes in inventory behaviour over the last 25 years, the author concluded that the "Good Luck" hypothesis, namely, the idea that the decline in macroeconomic volatility was simply related to smaller and/or less frequent macroeconomic shocks, was a much more likely explanation for falling variance of GDP growth.

"**A Model of Capacity Adjustment: Investment vs. Inventories"** by *John Tsoukalas and Christoph Görtz* of the University of Nottingham, School of Economics and Management, United Kingdom. The paper was presented by Christoph Görtz.

The authors studied the interaction between fixed investment and inventories in an environment where firms have to learn about the state of demand. The study was motivated by empirical evidence from the U.S. manufacturing sector that indicated investment in inventories led investment in fixed capital by several quarters.
An industry was studied where the typical firm can satisfy demand in two ways: by adjusting the level of output inventories holding capacity fixed or by raising output through capacity expansion by investing in capital. This problem became even more interesting when the firm had to learn whether a given change in demand was permanent or transitory. The intuition was that the firm could react to a shock with adjustments in the capital stock (extensive margin) or inventories (intensive margin). The trade-off between adjusting capital or inventories depends on the marginal cost of each action. Since investing in fixed capital was subject to adjustment costs the firm would adjust the latter only if it had a strong belief that the shock was permanent. If the firm on the other hand believed that the shock was transitory it would adjust inventories.
A model was built to analyze the problem where finished goods inventories arose due to stock-out considerations (as in Bils and Kahn (2000)) and investment in capital was subject to both convex and non-convex adjustment costs. The firm learnt about the nature of the shock affecting demand through Bayesian learning.

First the rational expectations (no learning) benchmark were analyzed and it was found that there was considerable interaction between investment in capital, inventories and employment.

In this environment investment in capital and inventories were positively correlated as in the data but this crucially depended on the level of capital. For a low level of capital the correlation was higher than for a high level of capital (because due to the fixed cost component investment was zero in this region). It was also found that employment was positively correlated with fixed investment but less so with inventory investment.

**"Inventory Management of Customer-Stockpile in a Competitive Market When Demand is Interdependent over Time"** by *Soheil Sibdari* of the University of Massachusetts, Department of Decision and Information Sciences, United States and *David Pyke* of the University of San Diego, School of Business Administration, United States. The paper was presented by Soheil Sibdari.

In this study, the authors contribute to the inventory management literature by developing a finite-horizon model for two firms offering substitutable and nonperishable products with different quality levels. Customers can purchase and store the products, even if they do not need them at the time, in order to use them in the future. The stockpile of the products generated by customers affects the demand in future periods. Therefore, the demand for each product is not only a function of prices and quality levels, but also of the products' stockpile levels. In addition, the stockpile levels change the customers' consumption behavior; more product in a stockpile leads to more consumption. Therefore, address not only the price and demand relationship was addressed but also the stockpiling and consumption relationship in a competitive environment. The decision variable of each firm at the beginning of each period is its unit sale price. A deterministic dynamic program was used to calculate the equilibrium prices at the beginning of each period. By assuming that the market stockpile is public information, the existence of a unique Nash equilibrium was shown. Next the authors considered the case when the firms did not know the market stockpile. Appropriate heuristics were then developed to calculate the optimal prices in each case. A numerical study was also provided to calculate the price levels in different scenarios and compare their performances.

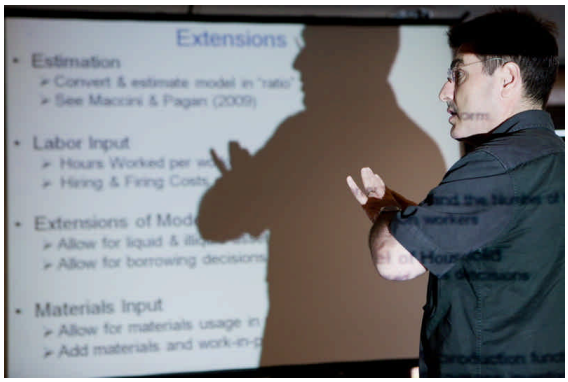
## Inventory Management

### AUGUST 23, 2010 ▸ IM1

by Oded Berman

Three papers were presented. The number of people that attended the session varied from 8 to 17. There was a common theme in the first two papers by *Berman* and *Gebennini* that dealt with centralized and non-centralized inventory system. The third paper presented by *Wee* though very interesting should have been assigned to a different session. There were few questions at the end of each talk (the third paper by Wee generated more questions).

The main conclusion of the paper presented by *Berman* was that even though for demand




distributions that do not allow negative realizations the benefits of pooling is declining when there is high variability of the demand, the system remains in the normal operation regime (when the order quantity increases) longer than in the non-centralized system. The paper presented by *Gebennini* compared centralized and non-centralized configurations of a multi–echelon distribution system. The work was done in collaboration with a distribution company in the beverage field. The main objective of the EOQ type

system discussed in the paper presented by Wee was to determine the optimal cycle length, order quantity and backorders for a single machine production system with uncertain breakdowns.

## AUGUST 24, 2010 ▸ IM2

by Anders Segerstedt

In this session two papers were presented:

The first presentation was "**Sustainable performance improvement and employee creativity in a lean warehouse environment**" presented by *Fons Naus*, Tilburg University, and with co-authors Job de Haan, Mark Overboom and An van Iwaaarden.
A survey was administered covering 108 warehouse employees of a large Dutch multination company, strongly dedicated to the implementation of lean management principles. The gap between the employees' need for creativity and the potential offered emerged as an important predictor of job satisfaction and turnover intent. In a follow up study value stream mapping were used to improve system performance and where employee creativity might be employed. A practical implication of the study is that combining person-work analysis and value stream mapping revealed areas for sustainable improvement of logistics processes. To ask for and implement employee suggestions this became both a creator and a consequence of increased worker motivation.

The second presentation was "**Repairable item inventory control with work-in-process (WIP) dependent base-stock levels**" by *Bariş Selçuk*, Bahçeşehir University. (This paper is a Service Logistics paper.)
This paper presents a conceptual mathematical model treating an adaptive base stock policy for a repairable item inventory control problem. Base stock level of a repairable item is updated based on the work-in-process (WIP) inventory level in repair facility with update frequency, *r*, modelled as a separate tactical control parameter together with a standard base stock level, $S_0$. Stock-out situations are handled by emergency shipments, and priority shipments are used when updating the base stock level. The problem is modelled by a two-dimensional continuous-time Markov chain, which is then solved explicitly by using matrix geometric methods. Numerical results are provided that show, for a given downtime target, it is possible to achieve savings in inventory on-hand by using the ($S_0$; *r*) procedure.

## AUGUST 24, 2010 ▸ IM3

by Gerald Reiner

During the IM3 session three presentations took place.
First, *Gerald Reiner* from the University of Neuchatel in Switzerland presented a "**Simulation Based Analysis of Buffer Configuration and Loading Policies: an Example from the Glass Industry**". He conducted this research together with his colleagues Boualem Rabta and Arda Alp from the University of Neuchatel. In particular, he presented an integrated analysis of buffer configuration and loading policies. Their study was motivated by the characteristics of the glass manufacturing industry. They aimed to find a feasible solution that can be applied within an empirical setting, i.e., their modeling approach overcomes the implementation disadvantages of optimization based on mathematical programming. In particular, they analyzed the dynamic dependencies based on simulation models between buffer configuration and loading policies and provided evidence for performance improvement (throughput increase and lead time reduction) without increasing the number of bottleneck resources. During the discussion at the end of the presentation the impact of different variability (process and demand) settings was of particular interest.

Second, *Jaehun Park* from the Pusan National University in South-Korea presented a "**Multi-criteria ABC inventory classification using cross-evaluation in DEA**". He conducted this research work together with his colleague Hyerim Bae from the Pusan National University. The main contribution of the presented research work was to propose a network DEA model, in order to solve a limitation of

traditional DEA application. In particular, these models can't consider on the one hand the relationships between production units in the system under consideration of inventory information and on the other hand between a production unit and the whole system. The classical efficiency scores maybe not able to present the "correct" aggregate performance of the processes of a production system. Thus the authors suggested an extended network DEA model that takes into account the interrelationships of inventory information among the unit processes within a production system. The main questions after the presentation was dealing with computation aspects related to the complex mathematical programming model.

Third, *Peter Kelle* from the Louisiana State University in the US presented "**Dual Sourcing with Capacity Reservation and Stochastic Spot Market Prices: Optimal Procurement Strategy and Heuristics**". He conducted this research study together with his colleagues Karl Inderfurth and Rainer Kleber from the University of Magdeburg in Germany. They analyzed combined sourcing decisions (i.e., purchasing based on capacity reservation contracts or buying on the sport market) under stochastic demand and random sport market price fluctuations. Purchasing decisions are in each period necessary. Peter Kelle presented this decision problem as a stochastic dynamic optimization problem and analyzed the optimal procurement strategy based on stochastic dynamic programming. On the one hand the presenter provided a proof that the optimal procurement decision can be made by a complex policy but on the other hand the calculation of the related parameters is difficult. Therefore the authors developed a "simple" heuristic for determining the related parameters. This approach is based on the solution of an adjusted newsvendor problem as well as the result of a simplified base stock policy. The main questions after the presentation were dealing with potential dynamic dependencies between different inventory positions (holding inventory), purchasing/capacity reservation price and the relevant policy parameters. Finally, potential constraints related to a limited number of capacity reservation periods (forward buying) were discussed.

## AUGUST 24, 2010 ▸ IM4

by Alan J. Stenger

The session consisted of three interesting papers: one on plant maintenance issues and two on retail inventories.

*Alan J, Stenger* presented a paper entitled "**Revisiting the Deployment of Safety Stocks in the Design of Complex Supply Chains**". One of the issues in the design of supply chains concerns the location and size of safety stocks for individual items in a multi-location, multi-echelon supply chain. The dilemma is this: the location of facilities (such as plants and distribution centers) depends in part on the physical volume of the demand placed on that facility and the choices of transportation options connecting facilities and the locations of demand. The usual way to design such a network of facilities is to employ mixed-integer programming techniques. In doing this we group individual items into "families". Transportation and shipment sizes to be used on the links between the various potential nodes (facility locations) are determined *a priori*. Aggregate inventory costs at a location are usually considered to have a fixed and variable relationship with the volume assigned to a facility, independent of the transportation choices. But inventories are a function of the order quantity (which depends on transportation costs, in part) and the safety stocks (which depend on the volume of the item through the facility, in part). All this makes it difficult to differentiate the assignment of individual stock-keeping units (SKUs) to individual locations. This becomes an issue, for example, when it might make sense to centralize stocks of slow-moving SKUs, and ship these items to customers directly from one or more central locations, while higher volume items are stocked in many more locations. Attempting to design a supply chain when differentiating SKUs in this way requires more careful analysis of transportation and inventory trade-offs, as well as determining ways to build these issues into mixed-integer programming techniques for supply chain design. This paper explored these issues and suggested some remedies, as well as needed further research.

The second paper, presented by *Ruggerio Golini*, was entitled "**Managing Lead Times and Inventories in Global Supply Chains**." Ruggerio dealt primarily with the moderating effect of global supply chain configuration on the relationship between supply chain improvement programs and performance improvement. While there are benefits to being operating global supply chains, there are also disadvantages: global supply chains are more complex than domestic supply chains, and often have higher levels of risk. The study utilized data from the 2009 Edition of the International Manufacturing Strategy Survey (IMSS V) to test for any relationships. The authors identify four general configurations of global supply chains, as determined by the percentages of sales, manufacturing, and sourcing done outside the home country of the firm: "Locals," "Barons," "Shoppers," and "Globals." Their conclusions: global supply chain configuration, in terms of percentage of sourcing and manufacturing and sales outside the continent, does affect the relationship between programs and performance. Some relationships that are significant for the overall sample become insignificant when considering single groups of companies representing different global supply chain configurations. At the same time, other relationships that are not significant for the whole sample are significant for one or more configurations.

The final paper of the session was presented by *Artur Swierczek*, entitled "**The Capabilities of Manufacturing Companies to Operate Global Supply Chains**". The study attempted to answer two key questions: 1. What are the actual main groups of indicators demonstrating the abilities of manufacturing companies to become a part of virtual supply chain? 2. What are the significant attributes of producers demonstrating different levels of adjustment to operate in virtual supply chains? In doing this work, the author used the following definition of a virtual supply chain: "production and distribution systems utilizing a formal physical network structure, and operating through a network of separate organizations" (Chandrashekar and Schary, 1999). Like the previous paper, this study used data from IMMS V. Responding firms included those in Europe, Asia, and North America. Most were discrete manufacturers. Using factor analysis and cluster analysis on a variety of firm operating variables, quality initiatives, and supply chain performance measures, the author arrived at three groups of firms defined as "virtual,". "medium virtual," and "non-virtual." He then reviewed the characteristics of each group. The study concluded that, in answer to question 1, that a number of factors can be identified as indicators of capability to be part of a virtual supply chain. And in answer to question 2, firms more likely to be operating in virtual supply chains tend to be larger, make-to-stock manufacturers with broad product lines who have sophisticated inventory management capabilities. However such firms are not limited to any one industry or country of origin.

Overall it was a very interesting and informative session.

## AUGUST 24, 2010 ▸ IM5

by Avijit Banerjee

The first of the three papers presented in this session, titled "**A study on the coordination of two-echelon supply chains using credit and quantity discount options**" (co-authored by R. Du, *A. Banerjee*, S. L. Kim and S. Banerjee), was presented by the session chair. This work examines the mechanisms of a credit (i.e. delayed) payment option and a wholesale price discount, for coordinating single product, two-echelon supply chains, where the product's market demand is determined by its retail price. Optimization models are developed from the perspectives of both members of the supply chain (i.e. the buyer and the supplier), as well as the entire supply chain, treated as an integrated entity. These models yield the individually, as well as jointly optimal retail price and the ordering policy for the buyer and the supplier's production/delivery, credit payment terms and wholesale pricing policies. It is shown that the employment of either or both of the coordination mechanisms generate additional profit for the whole supply chain. The sources of and the incentives for achieving such additional profit are clearly identified and a procedure is outlined for

sharing this gain in a fair and equitable manner. The concepts developed in this paper are demonstrated by a numerical example and a detailed sensitivity analysis is performed with respect to some selected problem parameters.

The second paper, titled "**Consignment stock policy for a two-level supply chain with defective items**" (co-authored by M. Khan, M. Y. Jaber, S. Zanoni and L. Zavanella), was presented by *Mohamad Jaber*. This paper studies a consignment stock policy in a single item, single vendor, single buyer two-level supply chain, where a fraction of the products manufactured by the vendor is defective. Each of the vendor's production batches is shipped periodically to the buyer's warehouse in equal sized delivery lots. A consignment policy implies that the vendor owns the inventory stored in the buyer's warehouse and, consequently, incurs the holding costs, until withdrawn for sale or use. The buyer employs a 100% inspection process to separate the defective items. Inventory withdrawals and consequent payments to the vendor are based on a constant market demand rate. In order to examine this scenario, a cost minimization model is developed. This model yields the vendor's optimal batch size and the number of shipments per batch. The results of a thorough numerical analysis show that the screening of the defective items increases the overall supply chain cost, which is, not surprisingly, dependent upon the fraction of defectives. This paper also addresses the issue of balancing the time devoted to the inspection process and contends that this time can be reduced by sacrificing the efficiency in intercepting defective items.

The final paper of the session, "**Analysis of an assemble-to-order system with different replenishment intervals**" (co-authored by G. Karaarslan, Ton de Kok and G. Kiesmüller), was presented by *Gönül Karaarslan*. This paper makes a distinction between complex and simple components used in assemble-to-order systems. The former type of components is generally more expensive and tends to have longer lead times, thus, warranting more frequent ordering. This study examines a single echelon system, where a single product is assembled from a complex and a simple component, whenever customer demand occurs. In formulating a mathematical model, demand is considered to be stochastic and backordering is allowed, whereas supply lead times for the components are assumed to be deterministic. It is also assumed that replenishment policies for both the items are based on periodic review systems, with known review periods. The analysis shows that the items' optimal ordering policies depend on the difference between their uncertainty periods (sum of review interval and lead time). Consequently, reasonable ordering policies are defined and the policy parameters, yielding minimum expected total cost per period, are derived. The conditions under which a balanced base stock policy is preferable over a pure base stock policy are outlined, pointing out that although the latter is easy to implement, the former is easier to compute. Finally, a numerical analysis is performed for investigating policy performance characteristics.

## AUGUST 24, 2010 ▸ IM6

**Stock Rationing With Multiple-Unit Demands And Varying Unit Size**

*Grigory Pishchulov,* European University Viadrina, Germany

The author considered a periodic-review base-stock control system with lost sales and dealt with the problem of optimal stock rationing between two consecutive replenishment opportunities in presence of multiple demand classes.

He assumed that a random demand of at most one class may arrive per discrete time interval. The demand realizations must not necessarily be multiples of the same quantity, and can be either declined, filled in full, or also filled partially in the amounts specific to the demand class and the demand realization. It is known that an optimal rationing policy cannot be described in this case in terms of critical reserve levels that would in each time interval guide the system to fill the incoming demands at most in the excess of the stock level over the respective class-specific reserve level. The problem has been solved by dynamic programming recursion and resort in each iteration to parametric mixed-integer programming for computing the

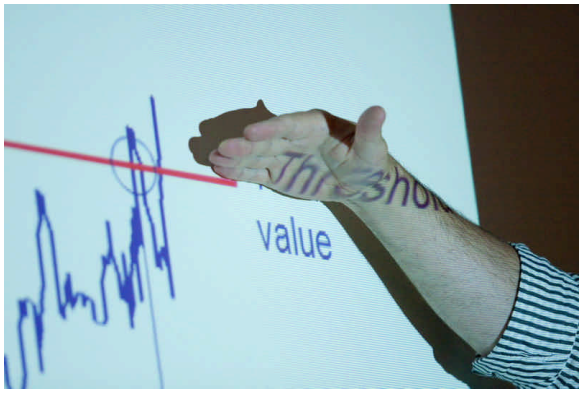
optimal value function. It can be shown that an optimal rationing policy can still be described by multiple critical levels per demand class and time interval.

**Optimal Time-Based Consolidation Policy With Price Sensitive Demand**
K. Hong, Chulung Lee
*Korea University, Information Management Engineering, South Korea*

In this paper a single-item inventory system was considered where shipments were consolidated to reduce the transportation cost using time-based consolidation policy. Time-based policy ships accumulated orders every *T* period and the time between successive shipment dispatches, called "shipment cycle". Under the time-based policy when the cumulative orders during shipment cycle exceed the on-hand inventory pre-specified quantity is replenished. Thus, the time-based consolidation policy consists of the shipment cycle and the replenishment quantity. In this paper, the authors considered price sensitive demand and developed an optimal time-based consolidation. The objective was to compute the optimal price, replenishment quantity and shipment cycle to maximize the total profit. The long-run average profit was computed and the optimal properties were obtained. It was proved that the long-run average profit was a concave function of price for given values of the replenishment quantity and the shipment cycle, and a closed form equation for the optimal price was provided. Thus, by substituting the price with replenishment quantity and shipment cycle in the profit function, the problem was reduced to compute the optimal replenishment quantity and the optimal shipment cycle only. It was proved that the average profit function was a concave function of shipment cycle and obtained an upper bound for the optimal replenishment quantity. Using the optimality conditions, a search algorithm was developed to obtain the optimal values of replenishment quantity and shipment cycle for the proposed policy. The computational complexity of the proposed search algorithm was polynomial. In order to compare the performance of the proposed policy and existing consolidation policy, the authors conducted extensive numerical experiments and compared the performance in terms of the resulting price and profit. The results from numerical experiments showed that average profit significantly increased using the proposed policies rather than the existing model without pricing.

**Joint Ordering And Inspection Policy For A Multi-Period Inventory System Subject To Shrinkage Errors**
*Yacine Rekik, EMLYON Business School, EFG, France*
*Evren Sahin, Yves Dallery, Ecole Centrale Paris, France*

For a majority of investigations, it is implicitly supposed that the level of the available inventory shown by the information system corresponds exactly to the physical quantity available. However, various factors can create a difference between the expected and the effective physical and information flows and perturb the synchronized evolution between these two flows. The authors considered an infinite horizon, single-stage, single-product periodic-review inventory in which inventory records were inaccurate. They assumed that inventory inaccuracies were introduced by shrinkage type errors that occurred within the store. They also assumed that an inspection policy was performed each a finite number of selling cycles. Two situations were proposed permitting to manage the joint ordering and inspection policy based on the information they had on shrinkage errors. The comparison between the two situations permitted to analyze the impact of shrinkage errors and the value of taking into account the inaccuracy issue when optimizing both the inventory and inspection policies.



## AUGUST 26, 2010 ▸ IM7

**A Life Cycle Model and Two Cases of OM Development (Implications for Inventory Management)**

*Attila Chikan,* Corvinus University of Budapest, Hungary
Linda Sprague, China Europe International Business School, Hungary

The paper analysed some aspects of the process of development of OM practice and the connected knowledge transfer. It described the development process as having a life cycle pattern which starts out from some "big idea" promising breakthrough results. It goes through the phases of provenance, experimentation, penetration and consolidation to absorption (when the business community accepts the new idea and builds it into the system of operations) or decline (when the original idea proves unsuccessful). A general life cycle model was presented and two illustrative cases were discussed: the development of MRP and SCM. They both proved successful and are today integrated part of company operation. However, even though the patterns of development over time are very similar, they led to rather different kinds of embedment of the two systems - MRP became a tool hidden in everyday tactical level operation while SCM is a strategic approach to integrated company management. Both MRP and SCM developments had a great impact on how inventories were viewed and handled both in actual management and in research. The nature and consequences of this impact were analysed in detail.

**The Impact of Human Resource Practices on Lean Production**

*Yoshiki Matsui*, *Phan Anh,* Yokohama National University, Japan
*Osam Sato,* Tokyo Keizai University, Japan
*Hideaki Kitanaka,* Takushoku University, Japan

Intending to best utilize manufacturing resources and achieve the highest productivity and profitability, JIT production or lean production depends on various practices on resource allocation and deployment. This paper focused on human resources or human capital as one of the most important manufacturing resources and analyzes the contribution of human resource practices concerning selection, promotion, training, communication, decision making, etc. to the implementation of lean production, using several statistical methods such as reliability analysis, factor analysis, canonical correlation, and regression models with the survey data from 238 manufacturing plants in industrialized countries. An international comparison on the role of human resource management was also made in order to derive the implications for practitioners who are responsible to promote lean production or lean supply chain.

**Distribution-Free Inventory Management**

*Michael Wagner*
Saint Mary's College of California, United States

Inventory management problems were studied in this paper where demands were revealed incrementally and procurement decisions must have been made before the demands were realized. There were neither probabilistic distributions nor non-trivial bounds to characterize demands. Using competitive analysis, a framework borrowed from Computer Science, the inventory management problem was approached from a worst-case perspective, which leads to risk-averse decisions. Two cost-minimization problems were considered: (1) perishable products with lost sales and (2) durable products with backlogged demand. Frameworks were designed, utilizing linear fractional programming and duality theory that allow a decision maker to design his or her own procurement strategy, based on exogenous preferences.

The first problem consisted of designing the procurement strategy for a single perishable product over a finite planning horizon with period-dependent costs. Three examples were provided of how to apply the framework to design strategies that correspond to the following decision maker criteria: (1) The performance guarantee is best possible; (2) the performance guarantee is defined

by the decision maker and (3) strengthen an existing procurement methodology.

The second problem consisted of designing the procurement and inventory management strategy for a single durable product that can be inventoried, over a finite planning horizon with period-dependent costs. Additionally, excess demand was backlogged for future periods. The framework was applied to provide an in-depth example of a Make-to-Order strategy that identified the best times to fulfil backlogged demand.

## AUGUST 26, 2010 ▸ IM8

by Kalevi Kyläheiko

There were three presentations in this session. They are introduced by the chairman below.

**Vendor-managed inventory for multiple customers under time-varying demand**
*Mehmet Gumus,* American University of Sharjah, United Arab Emirates
*Elizabeth Jewkes, James Bookbinder,* University of Waterloo, Canada

In this highly technical paper different vendor-managed inventory systems were analyzed. Vendor Managed Inventory (VMI) is a partnership that enables the vendor to order on behalf of customers. When coupled with consignment inventory (C&VMI), the vendor also owns the goods at the customer's premises until they are used. The presenters studied these supply chain practices for a vendor and multiple customers who face time-varying, but deterministic, external demand for a single product. Their aim was to select the right set of customers for a vendor under VMI and C&VMI. Therefore, they developed integer programming models when VMI and C&VMI are alternative options to the traditional way of doing business when customer initiates orders. They managed to show that it is in a customer's best interest to establish the right level of maximum inventory for vendor replenishments in each period. Various pretty confusing examples were used to compare and contrast the optimal solutions in traditional way of doing business, VMI, and C&VMI. Results indicate that if customers do not set the right levels for maximum-inventory under VMI or C&VMI, system-wide losses can be extremely high. With the right levels, percentage savings of C&VMI-customers are always greater than that of VMI-customers. On the other hand, the vendor always prefers VMI over C&VMI unless there are two or less customers. As the number of supply-chain customer's increase, number of VMI agreements also increase, but there will always be at most eight C&VMI agreements.
The authors concluded that success of VMI or C&VMI depends on the maximum inventory levels the customers allow. Moreover, C&VMI is a better option than VMI for any customer, but the vendor favors it only when there are a few customers in the supply chain. In any other case, VMI is a better option for the vendor. The problem with the presentation was that there was simply quite too much stuff for one paper and therefore the potential contributions remained a bit obscure, even if the presentation as such was quite ok.

**Determining the number of stacks in a mixed block stacking bay considering relocations**
*Dong-Won Jang, Kap Hwan Kim*
Pusan National University, Department of Industrial Engineering, South Korea

This paper addressed an optimal design method of storage systems in which unit loads are stored vertically, which is called the "block stacking storage system (BSSS)." One of the important problems in BSSS is relocations required when there exist unit loads on the top of the unit load to pick up next. Relocations are observed when multiple types of inventories are mixed in the same bay. The relocation is a major source of inefficiency during the handling operations in BSSS. This study addressed how to estimate the numbers of relocations during the retrieval process in various situations when the idea was to minimize the sum of inventory handling and space costs. The retrieval probability and the storage probability were defined formally and it was shown how they can be estimated from data on the duration of stay and the retrieval frequency of each type of unit loads. Three special cases were analyzed: the case where the retrieval probability is the same for all items; the

case where the retrieval probabilities of items are different among various items but are proportional to the number of unit loads of each item stored in a bay; the case where the retrieval probabilities of different items are different from each other and are not related to the number of stored unit loads of each item in the bay. The presentation was hard to follow and I am tempted to think that perhaps some simulation-based approaches would have been more effective. Also the connections to the former studies remained unclear.

**An optimal truck and train transportation of containers**

*Won Young Yun, Young Jin Han, Wen Fei Wang*
Pusan National University, Industrial Engineering Department, South Korea

In this highly technical paper, an intermodal transportation problem that involves one-depot and one station with time windows at both origins and destinations was dealt with. The basic idea was that to transport containers to the destination, the shipper should decide how to transport containers more efficiently on time. Containers are usually transported from origin to destination in inland transportation by truck, because it can serve door to door service quickly. However, the transportation cost is relatively high and we also consider another transportation mode that includes truck and freight train simultaneously.

In this paper, the presenters assumed an inland transportation network with one terminal, depot, train station, and customer places for inland transportation of one type of containers and minimized the sum of transportation costs. A meta heuristic algorithm based on taboo search was proposed to find the optimal solution to minimize the total transportation cost. The numerical results of the proposed method are compared to the solutions obtained by CPLEX. The presentation was also hard to follow, since there were quite too many different items involved. Also the connections to former studies that are many in this field remained largely unexplained. I am not sure whether there is that much novelty in this paper.

## AUGUST 27, 2010 ▸ IM9

by Serhan Duran

All speakers attended and presented their works. The session started and ended on time. The attendance was around 6-7 people other than the speakers. Specific comments on each talk are given below.

**Talk 1: Tactical Inventory and Backorder Decisions for Systems with Predictable Production Yield**

-A question is directed to the speaker about why backorder amount decreases as the lost sale cost increases. The speaker decided to check the computations again since that argument seems not intuitive.

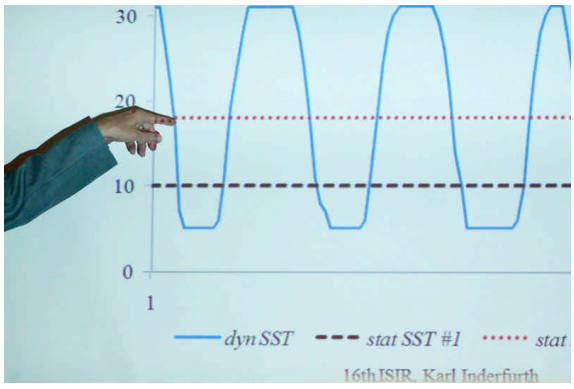
**Talk 2: Application of On-Demand Inventory Control Software to Fast-food Chain**

-A question is directed to the speaker by Dr. Yoshiki Matsui about what the Matsui Logic is. The speaker explained how that ratio is used within the model.

**Talk 3: Incorporating the Future Consequences of the Order Quantity Decision: A Two-period Newsvendor Model**

-The first question directed to the speaker by Dr. Serhan Duran about why demand today negatively effecting demand tomorrow and the speaker explained that it is due to the probability of having more annoyed people today.

-The second question directed to the speaker by Dr. Imre Dobos on if he is dividing the demand into two periods and the speaker explained that the demand of second period is dependent on the first period and the demand is not divided into two periods.



## AUGUST 27, 2010 ▸ IM10

by Linda G. Sprague

*Prof. Linda G. Sprague:* Session Chair and presenter
**"China's Evolving Supply Chain Infrastructure: the Hardware and the software"**
There was only one presentation for this session. The attendance was 12 people for the entire session plus 3 who left early to catch planes.

While China's industrial output continues to grow and develop in spite of world-wide industrial slowdowns, the status of the country's supply chain infrastructure becomes an increasingly serious issue. In response, Chinese governmental programs are already well underway to offer relief – at least in the long run. Many initiatives are complements to projects already underway; others are newer programs intended to anticipate and encourage increased improvement in domestic goods movements. It is worth noting that – to date – efforts have been focused first on *hardware* – highways, roads, rail, ports, power, vehicle production…

At the same time, social, economic and political programs are well underway with new initiatives appearing regularly. Developments along these lines are intended to improve the country's transportation and supply chain situation with a view towards supporting increased movement of people from primary to second and third sector employment, with particular interest on improving conditions within the primary sector. The ministry-level organizations which oversaw and staffed the staff of the Central Planning organizations have been closed, the quality of education is being examined, and substantial changes in the structure of the government are being studied…

This presentation described the current state of *hardware* projects and also examined the current (and more recent) focus on *software* projects from land reform and removal of all taxes from the peasants to the early days of China's first legal system to the demise of the *hukou* scheme. The country's future will affect and be affected by its evolving logistics and supply chain infrastructure.

## AUGUST 27, 2010 ▸ IM11

by Karin de Smidt-Destombes

**A Spare parts model with cold-standby redundancy on system level**
*K.S. de Smidt-Destombes* (VU University, Amsterdam, The Netherlands), N.P. van Elst, A.I. Barros (TNO Defence and Organisation, The Hague, The Netherlands), H. Mulder, J.A.M. Hontelez (University of Amsterdam, Amsterdam, The Netherlands)

This paper was presented by *Karin de Smidt-Destombes*. Since this was my own presentation I will only give you a short summary.

For highly complex technological systems like aircraft and military installations often high levels of availability are required. Consequences of downtime can have very serious repercussions, e.g. economic loss or safety hazards. To achieve high availability levels it is often profitable to replace failed components with new ones. The failed components are restored off-line. , and down time is limited to the replacement time. Of course spare parts are needed to perform this type of maintenance and the amount of spare parts therefore determines the availability of the systems. As always the costs for spare parts need to be controlled and different algorithms (exact algorithms and approximations) are presented to find the best combination of spare parts against the lowest costs possible.

**Simulation based spare part optimization in multi indenture systems**
I. Chung (Hyundai Rotem Company, Uiwang-Shi, South Korea), *W. Young Yun* (Pusan National University, South Korea)

This paper was presented by *Won Young Yun*.
Won Young Yun explained in his presentation multi indenture systems. These systems have a hierarchical structure of components with multiple levels. Repair of an item in one of the upper levels is done by replacing items at a lower level. Furthermore, a multi echelon repair organisation is assumed. As performance measures the costs and the service rate are considered. Service rate is

defined as the proportion of customers of whose failed products are repaired within the given time period. To estimate the total expected operation costs and the service rate a simulation model is used. Won Young Yun also showed some numerical examples.

**Spare parts classification and inventory management in durable goods industries – An empirical case study**
A. Bacchetti (University of Brescia, Italy and University of Salford, United Kingdom), F. Plebani, N. Saccani (University of Brescia, Italy), A.A. Syntetos (University of Salford, United Kingdom)

This paper was presented by *Francesca Plebani*. Francesca Plebani presented a method to classify spare parts for which she uses a multi criteria decision making tool. For easy category of spare parts, she develops specific inventory policies. She found 12 different classes of spare parts. With the aim of minimising the total costs, with respect to a certain service level target, different inventory policies are proposed for each category using a simulation tool. This classification was tested on Italian household appliances manufacturing companies. Stock levels, costs and service level (fill rate) were all improved with the use of this proposed framework.

## Mathematical Modelling

### AUGUST 23, 2010 ▸ M1

by Søren Glud Johansen

The audience ranged from 14 to 22 for the session where three interesting papers on perishable items were presented.

*Frederik Olsson*: **Simple evaluation of (R,Q) policies for inventory systems with continuous review and perishable items**
Based on the steady state behavior of a base-stock policy, Frederik Olsson presented a new approach for modeling the (R,Q) policy in case of backordering and constant lifetimes of items. His method is simple and performs significantly better than the method suggested by Chiu in a paper from 1995 published in EJOR. He pointed out that the inventory levels may be quite inaccurate if expiration of products is not taken into account in infinite lifetime models.

*Rene Haijema, Jan van der Wal and Nico van Dijk:* **Computing an optimal ordering policy and deriving a day dependent (s,S) rule for perishables in the presence of fixed ordering costs**
Motivated by managing inventories of blood platelet concentrates (BPCs), Rene Haijema presented an approach that combines the strengths of stochastic dynamic programming and simulation. The optimal policy is computed by solving a periodic Markov decision model, which is high-dimentional and therefore requires aggregation. Simpler rules, such as a day dependent (s,S) rule, are derived from frequency tables created by simulation of the optimal policy, and they are tested by simulation against the optimal policy. For the Dutch case on distributing BPCs to hospitals, one can significantly save ordering costs with only a slight effect on the outdating and the occurrence of shortages.

*Steffen Minner, Anna-Lena Beutel and Sandra Transchel*: **Inventory control for perishable items with correlated demands**
Stefan Minner presented an extension of the dynamic order quantity determination method proposed by him and Sandra Tranchel in a recent paper on inventory control of perishable items. The extension incorporates that, for food retailing, customer sales exhibit significant serial correlation. Based on expressions for the inventory level when the order to be placed arrives under the FIFO and LIFO issuing policies, the order quantity that achieves a desired marginal service level was determined and implemented in a simulation study.

## AUGUST 23, 2010 ▸ M2

by Robert W. Grubbström

In this session of the Mathematical Models of Inventories stream, three papers were presented within the areas of optimal dynamic lotsizing, supply chain vendor-buyer inventory systems, and optimal inventory policies in a dynamic stochastic system.

The first presentation, authored and presented by *Robert W. Grubbström*, Linköping Institute of Technology, Sweden, was entitled "**A Lagrangean approach to dynamic lotsizing**". The problem treated is the classical dynamic lotsizing problem, which has earlier been solved by, for instance, the Wagner-Whitin algorithm, or approximately, by the Silver-Meal heuristic algorithm. From earlier findings, the problem had been turned into an equivalent zero-one binary problem concerning to replenish or not to replenish at each point in time when there is a requirement. By formulating a Lagrangean function with binary decision variables, using the zero-one constraints as additions to the objective function, the necessary Kuhn-Tucker conditions for optimality were developed. In an example it was shown that these did not suffice to find the unique optimal solution in certain situations. The paper concluded that further conditions on optimality need to be analysed for unique results to be obtained.

A second contribution with the title "**A study on the benefits of vendor-managed inventory with competition**" was written and presented by *Joong Y. Son*, Grant MacEwan University, Edmonton, Canada. The basic question treated in this paper concerns how advantages may be created from managing inventories from an upstream position, rather than from the local agent alone. A simulation model had been built, in which relationships between various parameters on the global as well as the local levels were investigated. Differences in the behaviour of the system were compared for the two principles VMI (vendor-managed inventory) and LMI (local managed inventory). The studies showed that VMI principles gave more benefits in case the retailers were more homogeneous (having similar demand distributions) and that joint replenishment policies were more favourable, when retailers are more heterogeneous. The paper also offered some interesting insights into the design of incentive schemes in order to improve the supply chain performance as a whole.

The final presentation was given by *Michinori Sakaguchi*, Hiroshima Shuda University, Japan, and entitled "**Optimal policies for a dynamic inventory model**". The problem treated concerned a one-product multi-period inventory system when demand (its distribution) varied over time. Dynamic programming formulations led to recursive relations which could be solved in simple cases. The problem was regarded as a generalisation of the Newsboy problem with no setup cost, and with the objective to minimise the sum of purchasing, holding and shortage costs. Optimal policies and their economic order quantities were developed and solved for simple cases with decreasing average demand over time. The paper gave a clear perception of how much the complexity of the problem increases, when the demand distribution no longer is stationary.

## AUGUST 23, 2010 ▸ M3

by Jacob Wijngaard

We had three papers:
**Buyback and Return Policies for a Book Publishing Firm**,
*Imre Dobos and Agnes Wimmer*
The authors made it a joined presentation. The practical setting was told by Agnes Wimmer, the model used to tackle the problem was explained by Imre Dobos. The paper was about a publisher who has two distribution channels: a channel direct to the customers and a channel through wholesaler/retailers. The publisher faces the problem of how to allocate the stocks of a given newly published book to the wholesaler and the retailers, and how many copies to keep in stock for direct sales. The publisher has a buyback option. The distribution of the demand is unknown. A game theoretic approach is used. The news vendor problem plays an important role in the solution.

**Approaches to Inventory Management in Supply Chains: a Comparative Study**
*Andras Kovacs, Peter Egri, Tamas Kis and Jozsef Vancza*
The paper was presented by Andras Kovacs. He distinguished four different approaches to inventory management in supply chains:

- Decomposition (each company optimizes its own production and inventories)
- Integration (assuming full trust and information, optimizing the total supply chain)
- Coordination (self interested-partners adopt some coordination scheme to realize some synergy)
- Bi-level approach (the partner who decides first takes into account the response of the partner)

Each of the approaches was illustrated with a simple two-level lot sizing problem.

**A Literature Review about Kanban and Conwip**
*Jan-Arne Pettersen and Anders Segerstedt*
Anders Segerstedt presented the paper. He described a very extensive literature review about pull based systems, especially Kan ban and Conwip. ISI Web of Knowledge and Scopus were the sources. An important point explored was the set performance measures that are used in the various studies. How are pull based production systems controlled to achieve performance? Has the research of pull based production systems changed over time? Which articles are cited most? Who are the most influential authors and in what journals is the research published?

## AUGUST 24, 2010 ▸ M4

by Karel van Donselaar

In this session three presentations were given, all dealing with research questions related to distribution systems in which limited inventory has to be allocated among multiple customers, having potentially different characteristics.

The first paper was presented by *Christian Howard* from Lund University in Sweden. It deals with allocation policies in a divergent inventory system with shipment consolidation. The authors consider a one-warehouse N-retailer inventory system having access to real-time point-of-sale data. The inventory in this system is reviewed continuously, while a consolidated shipment to all retailers is dispatched from the warehouse at regular time intervals. Their main research question is to determine in which situations state-dependent myopic allocation policies significantly outperform a simple FCFS (First-Come-First-Serve) rule to allocate shipped goods to the retailers. The myopic policies enable the warehouse to postpone the allocation decision to the moment of shipment or delivery, and to base it on the inventory information available at those times. Their numerical study shows that, even though myopic allocation can hold a significant advantage in some cases, the FCFS allocation policy performs well in most situations. The study also shows that situations where the myopic policies do tend to outperform FCFS are characterized by relatively long transportation times between the warehouse and the retailers, and small order quantities at the central warehouse. The discussion after the presentation highlighted in which situations the myopic policy might be applicable in practice.

The second paper was presented by *Da Wang* from Tongji University in China. He considered an alternative way of rationing inventory by considering multiple demand classes and different backorder treatments. He distinguished situations in which some customers imply penalty costs, while other customers face service restrictions. The paper considers two settings: a deterministic and a stochastic setting. For the deterministic setting the authors evaluate three models, assuming different treatment, equal treatment and different treatment with rationing. They show the last model outperforms the first model both in costs and in service level. Since the stochastic setting is more complex to analyze, they developed a heuristic and show this heuristic performs similar to another search method they developed to find the optimum.

The third paper was presented by *Olof Stenius* from Lund University, Sweden.
The paper considers basically the same distribution system as the first paper in this session. The research question however is different. The authors derive the

probability distribution of the shipment size to each retailer group, i.e., the amount of goods on each shipment. They obtain this probability distribution by dividing the shipment quantity into two parts; (i) items that satisfies retailer orders placed during the last shipment interval, and (ii) backorders associated with earlier orders that now are being shipped. By combining these correlated distributions they obtain the distribution of the total shipment size. Their results can be used to generalize integral models for distribution system optimization which include both inventory holding and transportation costs.

## AUGUST 24, 2010 ▸ M6

by Frank Van den broecke

**Sensitivity of two-stage multi-product economic lotsizing models and their dependency on change-over and product cost ratios.**
*Frank Van den Broecke* / Co-authors: El-Houssaine Aghezzaf, Hendrik Van Landeghem

The presentation tackled the problem of 'how to connect' operations within a two-stage production system:

1. Physically connect them and treat the process as one operation.
2. Leave disconnected and optimize each operation independently.
3. Establish a synchronization process between both production stages.

In a simplified single product setting, the presenter claims (based on mathematical calculus) that the optimal two-stage production frequency corresponds with the single EOQ solution for the first stage. A sensitivity study revealed, within these two-stage lotsizing models, the economical cost dependency on product and change-over cost ratio's.

A numerical example (X-ray film) sustained the conclusion about the optimal settings remain valid when extending the model to a two-stage multi-product setting. The author claims that two-stage individually optimized EOQ lotsizing should only be used when the end-product stage has a high added value and small change-over costs, compared to the first stage. Physically connected operations should be used when the end-product stage has a small added value and low change-over costs, or high added value and large change-over costs compared to the first production stage.
The main critics on the presentation remarked that only one (Agfa) company example was used and that the proposed model did not consider a finite capacity constraint.

**A savings heuristic and lower bound for placing strategic safety stock in supply chains**
*Jörn Grahl* / Co-author: Franz Rothlauf

Optimising safety stock positions within a guaranteed service approach model, is a NP-hard problem and practically unsolvable for large and complex industrial instances. The authors propose a heuristic to establish a lower bound for the problem. Understanding the lower bound results indicates the position of the optimal solution.

The proposed heuristic is tested out on a serial assembly system assuming infinite capacity. The heuristic is tested for different levels of variability within the end-customer demands. At some distinct nodes variability increases caused by the bill-of-material relations within the assembly system.

The heuristic starts with an initial solution where each location has safety stock to cover its processing time. Step by step, based on a greedy approach, it merges coverage times of two stock points, removing all safety stock at the more upstream position.

Within a serial system the heuristic works well and solves all instances to optimality. The lower bound's distance to the optimum is on average 10% over all instances and 5% for high service levels. On the other hand within general acyclic systems the gap between bound and best-known solutions remain high, approximately 40% on average.

An interesting remark, after the presentation pointed at the resemblance towards project planning with the well known critical path method. It seems obvious to put safety stock at the critical nodes.

**A comparison of metaheuristics for strategic safety stock allocation in supply chains**
*Jörn Grahl* / co-authors: Daniel Dittmar, Stefan Minner

Optimising safety stock positions within a guaranteed service approach model, is a NP-hard problem within general networks and practically unsolvable for large and complex industrial instances. The authors evaluate distinct metaheuristic approaches within serial, divergent and convergent systems.
The studied metaheuristics are based on (1+1)EA : Evolutionary algorithm, SGA : Simple genetic algorithm and BOA : Bayesian optimization approach. All metaheuristic methods provide reliable and similar results for modest serial and divergent systems. For convergent systems the SGA and BOA approach outclasses the (1+1)EA heuristic. In case models become quite larger the BOA approach clearly delivers the best results.

## AUGUST 24, 2010 ▸ M7

by Stefan Minner

The two presentations delivered in the session dealt with multiple supplier inventory models. *Ali Cheaitou*, Euromed Management France, presented the paper **"Finite Horizon Stochastic Inventory Problem with Two Procurement Modes: Near-Myopic Bounds"** co-authored by Christian Van Delft, Zied Jemai, and Yves Dallery. The complex problem of periodic replenishment from two suppliers with offsetting cost and lead times under a finite planning horizon and non-stationary demand was modeled as a stochastic dynamic program. Using traditional functional equation analysis, lower and upper bounds for the optimal solution were presented and a myopic heuristic developed.

The second paper "**Inventory Management of Platelets in Hospitals: Optimal Inventory Policy for Perishable Products with Emergency Replenishments**" was presented by *Deming Zhou* from the Chinese University of Hong Kong, co-authored by Lawrence Leung. This paper deals with an important problem in healthcare logistics for the supply of blood. It combines the two in itself challenging problems of procurement using multiple supply modes with the problem of perishable products. The procurement policy uses regular supply once in a cycle and allows for emergency order-up-to replenishments during the cycle. Based on properties of the optimal procurement policy, a heuristic was developed and numerical illustrations provided.

## AUGUST 24, 2010 ▸ M8

by Jörn Grahl

**Aggregate Constrained Inventory Systems with Independent Multi-Product Demand: Control Practices and Theoretical Limitations**
*Steven De Schrijver* - El-Houssaine Aghezzaf - Hendrik Vanmaele
The first presentation gave a comprehensive literature review on different types of aggregate constrained inventory systems with independent multi-product demands. The presentation went smooth and without any problems (just like the whole session went smooth and without issues). De Schrijver did not incorporate multi-item models with deterministic dynamic demand like in his review, which was not the focus of the work. The presentation gave the audience a wide and profound view on the models that have been developed and how these models interact and are related to each other.

**Travel Time Analysis for Multi-Shuttle AS/RS with Class Based Storage and Multi-Command Cycles**
Riccardo Accorsi - *Marco Bortolini* - Mauro Gamberi - Riccardo Manzini - Alberto Regattieri
The second presentation was on the analysis of travel times in automated storage and retrieval systems with ABC-based storage and multi-command cycles. This presentation was more engineering-based than the first one and originated from some practical work of the authors. It presented a way to approximate the complex travel times of an automated picking system using simulation. The presentation was lively and gave a fascinating view on the physical processes inside storage aisles. The author of this and the next

presentation were from the same school and could make some contact with the audience who were working on similar topics. In the discussion the presenter made clear that the travel time analysis could also be used when the automated storage system picked from both sides of the aisle.

**Storage Assignment Rules and Travel time Minimization in an Order Picking System** Riccardo Manzini - *Riccardo Accorsi* - Marco Bortolini - Mauro Gamberi - Cristina Mora
The last presentation was on a similar topic from the same group. Again the work was initiated from a practical problem. It considered the choice of storage assignment rules and travel time minimization in an order picking system. Using a large comparison study the authors concluded how to combine different storage assignment rules and minimization schemes as to effectively minimize the travel times in a real picking system.

Summarizing, the session went smoothly. It was only lightly attended with some visitors so that the discussion was limited. Still the presenters could make some contacts with the audience because the visitors worked on a similar research area.

## AUGUST 24, 2010 ▸ M9

by Werner Jammernegg

Originally, in the session two papers were scheduled:

Sandra Transchel/ Beutel/ Minner: **Joint pricing and inventory decisions under stockout-based susbstitution** (Presenter: *Sandra Transchel*, Pennstate University),

*Johannes Fichtinger*, Cranfield University: **Single period inventory control & pricing with spectral measures of risk**

About 12 to 15 persons attended these interesting and clear presentations which were followed by a constructive discussion.

During the first presentation Agostino Bruzzone informed the chairman that there will be a third presentation in the session (Unfortunately the chairman did not check the blackboard with the changes in the schedule). Bruzzone had to leave the session to give his own presentation in session S4 where he was scheduled as second speaker.

The chairman announced that there will be a third presentation in the session:

*Cimino/ Longo/ Mirabelli*: **Products return flows in inventory management: a general framework based on a supply chain simulator** (Presenter: ***Agostino Bruzzone***, University of Genoa).

Because of an accident the scheduled presenter Antonio Cimino, University of Calabria, could not attend the symposium. The first two speakers and the chairman listened to Agostino Bruzzone who did a good job in presenting the slides of his colleagues from southern Italy.

## AUGUST 26, 2010 ▸ M10

by Fredrik Olsson

This session included three presentations. The main theme in these presentations was inventory control models with lost sales.

*Sören Glud Johansen*: **Continuous review, Lost-sales Inventory Models with Poisson Demand, a Fixed Lead Time and No Fixed Order Cost**

This paper considers a continuous review inventory system for slow-moving and expensive spare parts for which the replenishment leadtime is relatively long. Customer demands are assumed to be lost if there is no stock at hand when the demands occur. Three replenishment policies are investigated; the pure base-stock policy (PBSP), the so called simple delay policy (SDP) and the so called full delay policy (FDP). From a simulation study it can be concluded that the SDP-policy performs better than the other policies for all cases considered. The proposed model in this paper is also compared to the heuristic suggested by Hill (2007), who considers exactly the same system. In this paper it is shown, that by choosing the lower bound on the delay

between the placements of successive replenishment orders differently, compared to Hill (2007), substantial cost reductions can be achieved.

*Werner Jammernegg and Peter Kischka*: **Risk Preferences of a Newsvendor with Service and Loss Constraints**

This paper investigates the problem of using the classical newsvendor model in situations where the manager is interested in other performance measures than expected profit. Using ideas from the classical newsvendor approach, this paper presents a new way of determining an order quantity that can be based on different performance measures. After having determined the optimal order quantity by applying the newsvendor model with a mean-deviation rule as an objective function, the authors analyze relations between the prescribed performance measures and the profit value of the product. Moreover, given a certain service level and loss constraints the authors derive conditions which characterize the risk preference of the newsvendor by analyzing the relations between the service level and the profit value of the product. In this case, it turns out that, the newsvendor tends to become a risk-taker for large order quantities when the probability of loss is relatively high.

*Karel van Donselaar and Rob Broekmeulen:* **Determination of Safety Stocks in a Lost Sales Inventory System with Periodic Review, Positive Lead-Time, Lot-Sizing and a target fill rate**

This paper considers a classical inventory problem with lost sales. The system is monitored periodically and lead-times are non-negligible. Demand is assumed to follow a discrete stochastic distribution and orders are made in multiples of a given batch size. The main goal of this paper is to derive an expression for the fill rate, which is not an easy task due to the lost sales assumption. Therefore, an approximation for the fill rate is developed. In this case this is achieved by applying linear regression using both analytical results as well as results obtained from simulation. The heuristic method is shown to be very fast and accurate.

## AUGUST 26, 2010 ▸ M11

**Single Buyer, Multiple Supplier Coordination with Shipping Frequencies**
*Stefan Minner*, University of Vienna, Austria
*Behrooz Pourghannad*, University of Science and Culture, Iran

There exist several advantages for having a supply base with multiple parties. Other than frequently stated risk and economies of scale arguments, the authors consider a situation where a single supplier is too small to satisfy the buyer's requirements due to finite production rates. Using a two-stage EPQ-type framework, they develop a method that simultaneously determines supplier choice, supply allocation, and the ordering policies between the buyer and the suppliers. Existing approaches are extended from the literature that assume that all supplies need to be put on a common replenishment cycle and each supplier delivers exactly once in a cycle. Specifically, inspired by approaches that perform well for the Economic Lot Scheduling Problem it is assumed that an integer number of times a supplier can ship available items in an overall replenishment cycle. The authors present an algorithm that finds the centralized minimal cost supply strategy and illustrate the improvements and (limiting) implications of restricting the multi-sourcing strategy to common cycle policies.

**A Greedy Algorithm for a Multiple Sourcing - Multiple Plant Supply Chain Model**
*Stefanos Katsavounis, Maria Kligkatsi*
Demokritos University of Thrace, Greece

In this paper a greedy type heuristic algorithm is presented that formulates and solves a multiple sourcing - multiple plant supply chain problem with capacity and lead time constraints, so as to find a minimum total procurement cost of raw materials. The model uses a set of independent, non-competing plants belonging to a production firm and a set of independent and competitive suppliers. During a production horizon a deterministic demand of products has to be satisfied in each plant using concrete quantities of non-perishable raw materials. The following data

are known in advance for each plant: type, quantity and deterministic desirable suppliers' lead time for each raw material, limited inventory buffer, previous horizon unused inventory with the associated holding cost and penalty cost due to delays in production. Inventories transportation among different plants is not allowed. Furthermore, for each supplier the set of raw materials that can supply the plants, the limited productivity, the associated costs (including transportation, production, holding and warehouse costs), the deterministic lead times and the minimum order quantities are also known. Due to limitations imposed by the customers the desirable supplier's lead time is the primary crucial parameter. The algorithm uses this parameter as the first priority rule and then focuses on cost, without violating the relative constraints and breaking all possible ties with predetermined priority rules. The algorithm finds a minimum cost feasible solution for the whole firm, whenever such a solution exists, which detects the set of triplets supplier – quantity of raw material - plant that has the greatest reduction on the total cost and gives an approximated optimal solution. Two alternatives are tested. At first it is examined the feasibility of a solution without violating the desirable suppliers' lead times and secondly the existence of a solution including penalty costs arise from suppliers' excess of the corresponding lead times. In both cases the total cost is calculated.

**Single-Cycle Policies for a Single-Vendor Two-Buyer System with Permissible Delay in Payments**

*Beatriz Abdul-Jalbar, José M. Gutiérrez, Marcos Colebrook, Joaquín Sicilia*
La Laguna University, Estadística, Investigación Operativa y Computación, Spain

In today's competitive markets it is very common that supplier offers the buyers a delay of a fixed time period to settle the amount owed to him. This strategy is advantageous for the supplier not only because encourages customers to order more, but also attracts new customers. In addition, permissible delay in payments also has benefits for the buyers since they do not have to pay the vendor immediately after they receive the items. In contrast, the buyers can delay the payment until the end of the allowed period and during the credit period they can earn interest on the accumulated revenues. However, if the payment is not settled by the end of the credit period a higher interest is charged.

Most of the papers on inventory models with permissible delay in payments analyze the problem from the buyers' point of view. That is, they focus on determining replenishment policies which minimize the total cost at the buyers without taking into account the total cost at the vendor. However, it is well-known that integrated inventory models usually have the advantage of reducing total cost. Many references can be found in the literature dealing with the case where the vendor and the buyers collaborate and integrate their decision processes, but most of them assume that buyers pay the vendor as soon as they receive the items. In contrast, there are few contributions on the integrated model assuming permissible delay in payments and, in general, they are confined to considering a single buyer. The main goal of this paper is to extend the analysis to the case where the vendor supplies an item to two different buyers which face a constant deterministic demand. It is assumed that each shipment from the outside supplier to the vendor or from the vendor to the buyers incurs a fixed setup cost. In addition, at each facility there is a holding cost per unit stored and replenishments are instantaneous. Under these assumptions the problem is formulated and solved in terms of single-cycle policies.

**Inventory Systems with Variable Capacity**

*Ilkyeong Moon, Byunghyun Ha*, Pusan National University, South Korea
*Byunghyun Ha*, LG Electronics, R&D Group, South Korea

Many complex production/inventory systems are characterized by uncertain capacities due to imperfect facilities and processes. In a real-life production/inventory system, an assumption that the time of arrival of goods is deterministic or that the received amount exactly equals the quantity ordered may not be tenable. Uncertainty of supply may arise due to variable supplier capacities and random yields. First, the supplier capacity is considered variable. There are many factors that cause the supplier's capacity to be variable.

Unexpected breakdowns and unplanned maintenance may result in down times of uncertain duration; an uncertain duration of repair may affect the availability of the facility, even when the repair is planned; and strikes are possible causes of uncertainty in supply. Second, the yield of the item is considered random. Random yields in a production environment are often due to imperfect processes: a random portion of the items processed turns out to be defective. The model is extended with variable supplier capacity in several directions and the authors analyze the effects of variable supplier capacity. First, a lot-sizing problem is investigated in an EOQ model with variable supplier capacity and random yield. Second, an EOQ model is developed with storage or investment constraints when multiple items are considered. Third, a distribution-free approach (DFA) is applied to the (Q, r) model with variable supplier capacity. Finally, sensitivity analysis of the optimal solution with respect to the parameters of the system is carried out.

## AUGUST 26, 2010 ▸ M12

by Marija Bogataj

Four theoretical papers have been allocated for presentation in this session.

**Transportation Delays in Reverse Logistics** written by Robert W. Grubbström and Marija Bogataj, **A Simple Closed Economic System Subject to Disruptions Analysed in Terms of MRP Theory**, the theory developed by David Bogataj and Robert Grubbström.

In the presentation of supply chain model which include reverse logistics the authors Grubbström and Bogataj explained how well developed MRP Theory could be extended from manufacturing to distribution, consumption and reverse logistic part of a supply chain model. They have demonstrated how the versatility obtained from combining input-output analysis and Laplace transforms enabling an analysis of a supply chain. The main difference between classical MRP model and supply chain model is in assumption that in MRP systems transportation time delays are not studied separately from production delay, while in supply chain models it is necessary and transportation delay could become one of the main factors influencing net present value and appropriate timing. Activity levels which are governing the speed of the respective processes at different locations, in general, are considered as decision variable which is very much dependent on transportation lead time. Special attention has been given to reverse logistics problems and modelling the production function of a reverse logistics node in the supply chain.Net present value was used as a measure of the performance.

In MRP Theory developed by Grubbström, matrices from Input-Output Analysis are used on the one hand for capturing the technical relationships of the transformation of goods and services in the value chain; on the other hand, Laplace transforms are applied for the sake of describing how the timing properties of transformation (extraction, production, and distribution) affect the system. The use of transforms also enables stochastic properties to be efficiently handled, as well as economic consequences to be determined by means of a Net Present Value analysis. These advantages have been used in the paper of David Bogataj and Robert W. Grubbström when describing a simple closed economic system subject to disruptions.

In the basic theory and methodology the authors discussed the model where production intensity is supposed to be described as exponential function The net production is determined as (**G** - **H**)**P**, where in general **P** (and thereby net production) is a time-varying vector-valued function, here they assumed that $\mathbf{P} = \mathbf{P}_0 e^{rt}$ where r describes the growth of intensity of flows. The growth could be disrupted. Key value drivers of a supply chain are streams of added values and the appropriate risk – adjusted required rate of return, typically expressed as a capitalization rate. Capitalization rate $s$ , which appear in frequency domain as frequency, in time domain appears as capitalization rate. It is the difference between discount rate $\rho$ , being the sum of risk free rate $\rho_{rf}$ and the risk premium $\rho_{rp}$ , and growth rate $r$ . The paper is contributing to the maximization of the economic value of the chain as

the discounted value of expected future cash flows by reducing economic harm which is rising from one or more of the following sources: (a) the change in the discount rate, (b) a reduction in future income, (c) reduction in the value of existing wealth or (d) an increase in future expenditure.

*Refik Güllü* presented the results of research achieved together with Damla Tomsuk under the title: **Analysis of a Two-echelon Supply Chain with Disruptions in Supply.**

In this paper a supply chain has been discussed which consists of a central warehouse and two retailers. The authors have considered the condition that there is uncertainty regarding the stock replenishments. In the system that they analyzed, the central warehouse was supposed to have the opportunity to replenish the system-wide stock at the beginning of each planning period. The central warehouse was making decision how much stock to allocate to each retailer. After stock allocation, customer demands and costs are observed at the retailers at each location. This framework which is well known and commonly considered in supply chain/multi-echelon inventory literature has been modified. Their study differs from previous works in two respects, namely the central warehouse may not be able to realize a stock replenishment due to supply disruption and the demands observed at the retailers are deterministic and non-stationary. The policies are suggested that aim to minimize system-wide costs over a finite planning horizon.

The final presentation was given by *Imre Dobos and Miklós Pintér* under the title: **The Analysis of Bullwhip Effect in an Arrow-Karlin-type Supply Chain.**

In the presentation Dobos and Pintér have investigated the bullwhip effect of supply chains using Arrow-Karlin approach. In the model linear-convex costs functional was assumed, when both decision makers minimize the relevant costs. Two cases have been examined: supplier and manufacturer minimize the relevant costs decentralized, and a centralized decision rule. They have shown how to distribute the gain in a centralized cooperation for optimal total supply chain achievements.

## AUGUST 27, 2010 ▸ M13

by Stanislaw Bylka

Two papers were scheduled for the early morning session on the last day of the Symposium. This session had an audience of around 12 people. The two papers make use of two different modeling approaches to investigate two quite different topics. Nevertheless, they presented some relations between the manufacturer (supplier) and the buyer (customer).

*Stanisław Bylka* (Poland): **Non-cooperative Consignment Stock Strategies for Management in Supply Chain**

The paper presented by *S. Bylka (Institute of Computer Science, Polish Academy of Sciences, Warsaw, Poland)* analyzes the coordination and competition issue in a two-level supply chain, having one vendor (or manufacturer) and one buyer (or retailer). To satisfy the buyer's continuous deterministic demands, the product is delivered in discrete batches from the vendor's stock to the buyer's. The inventory patterns and the cost structure of production - distribution cycles (PDC) under generalised consignment stock (CS) policies was presented. For the joint optimization case, the average total cost of production, shipment and stockholding is minimized. Optimal solution techniques were illustrated with numerical example.
In a competitive situation, the objective is to determine schedules, which minimize the individual average total costs in the PDC obtainable by individual decisions. The second part of this paper presents a non-cooperative two-person constrained game with agents (a vendor and a buyer) choosing the number and sizes of deliveries. Generalised CS-policies where considered as feasible individual strategies in the game. The class of non--cooperative sub-games, indexed by two integer parameters connected with CS policies was defined. The main theorem states that there exists unique Nash equilibrium strategy in each of the considered sub-game.

*Hui-Ming Teng, Ping-Hui Hsu, Hui Ming Wee, Yu-Fang Chiu* (Taiwan): **Optimal Period Replacement Decisions for Repairable Products with Pricing Warranty cost**

The second paper in this session was presented by *H.-M. Teng (Department of Industrial and Systems Engineering, Chung Yuan Christian University, Chungli, Taiwan)*. Warranty is a guarantee to the buyer in the form of a contract. Generally, it is provided by the manufacturer to customers for its product or services. The supplier has the responsibility to replace the parts of the product at each failure under warranty. To avoid too many failures, the supplier supports one or more replacements during warranty period. The purpose of this paper is to identify the optimal replacement period by minimizing the expected warranty cost (for given the failure rate function). This cost is defined and investigated with respect to the number of replacements. The basic idea is to prove of convexity of considered expected warranty cost functions. A comparison among the different frequencies of replacement under Veibull failure rate function is given by a numerical example.

## AUGUST 27, 2010 ▸ M14

by Peter Kelle

An important and challenging problem is the management of perishable items that has recently got more focus because of increasing cost effects and environmental concerns. The section M14 was addressing the different aspects of perishable inventory management. The classical field of perishable goods inventory management has been extended by considering price management jointly with inventory management and buyer-supplier cooperation. The first presentation of the section concentrated on the bundle price option that motivates the buyers to buy old items jointly with fresh items. The second paper applied control theory and derived a closed-loop relationship between the optimal selling price (control variable) and the optimal inventory level (state variable). The last paper of the session discussed a collaborative strategy between buyer and supplier for deteriorating products including trade credit.

The first speaker, *Hiroaki Ishii* (co-authored by Kenta Nakamura) discussed "**Perishable inventory problem with bundles**". The paper considers the bundle sale for perishable inventory, and seeks an optimal ordering quantity and price of a bundle. From the view of environmental point and recent high cost of outdating, it is very important to reduce the amount of outdating and it motivates the bundle sale. The maximum lifetime of the perishable commodity is 2 periods, unit selling prices for the commodity with remaining life time 2 and 1 are r1 and r2 ($r1 < r2$) respectively, and further bundle sale price is r ($r \le r1+r2$). With some percentage g(r) of customers buys the bundle set consisting of both remaining life time 1 and 2 commodities if both are available. Under the above setting, they derive the expected shortage quantity then the expected profit function with respect to y and r and discuss some properties of an optimal solution (y*, r).

*Xiaoqiang Cai* (co-authors Ying Feng, Yongjian Li, and Fengsheng Tu) presented the paper: "**Optimal Pricing Policy of a Deteriorating Product by Dynamic Tracking Control**". It is a study of the optimal selling price of a deteriorating product in both cases of finite and infinite time horizon, where the inventory holding cost can be expressed as a quadratic function of the current inventory level. In the case of the finite time horizon, they develop a model by taking into account the deteriorating dynamics of the product, and show its equivalence to a generalized optimal control problem of a linear quadratic form, i.e. an optimal dynamic tracking problem with a constraint on the control variable. An approximate optimal pricing policy is derived based on the Maximum Principle. The control policy takes a state feedback form, i.e. it exhibits a closed-loop relationship between the optimal selling price (control variable) and the optimal inventory level (state variable). Computational results are reported, to illustrate the effectiveness of the control policies developed.

*Yu Jonas* (co-authors H.M. Wee and J.H.Wu) presented the last paper of the session: **"A Collaborative Strategy for Deteriorating Inventory**

**System with Imperfect Items and Supplier Credits"**. In this study, they develop a deteriorating inventory system consisting of one supplier and one buyer. The system considers supplier-buyer collaboration and trade credit. The objective is to maximize the total profit of the whole system when shortage is completely backordered. In order to compensate the buyer's shortage loss, the vendor allows the buyer's delay payment. Three proposed mathematical models demonstrate how a collaborative approach to decision making can achieve a global optimum. A negotiation mechanism is incorporated to share fairly the profit between the players. The sensitivity analyses of the demand rate, replenishment rate, deterioration factor, and other related parameters show that the collaboration strategy and the deterioration factor have significantly affect the percentage of the extra total profit.
This was one of the last sessions of the conference so even with the importance of the topic the attendance size was not large and also the discussions were short. There were questions about the validity of quadratic inventory holding cost function assumed in the optimal control policy paper and about the way profit shared between partners in the collaborative strategy paper.

## AUGUST 27, 2010 ▸ M15

by Imre Dobos

There were three presentations, most of all on the research field "supplier-buyer" relationship.

The first presentation was held by *Professor Moon* with the title "**Coordinated inventory policy freight consolidation in a supply chain**". The paper examined a manufacturer and customer relationship in an EOQ-type inventory model. The difficulty of the model is that the authors have modelled the situation as a three-level supply chain. The basic manufacturer-customer relationship was extended with transportation possibilities. The paper has offered an optimal inventory holding policy to minimize the relevant costs. The results of the paper are demonstrated with the help of numerical examples.

The next presentation was provided by *Professor Bookbinder*. He investigated a supply chain coordination tool: quantity discount. The title of the paper is "**Determining a supplier's discount schedule for a family of items**". The innovation of the contribution is that the authors of the paper analyze the discount phenomenon from the perspective of the supplier and not from the view point of the buyer. They have applied to this problem an EOQ-type inventory model. The presentation has shown a payoff function of the supplier which is near to a game theoretic phenomenon.

The third, last presentation was held by *Professor van der Sluis*. This presentation is slightly different to that of the first two presentations. The title of the paper is "**Simple heuristic approach for coordinating replenishments**". The author has presented three basic models of inventory management to demonstrate the numerical difficulty of the determination of the optimal inventory holding policies in these models. The first model was the Joint Replenishment Problem (JRP). The difficulty of the determination of the optimal policy is aroused from the problem that the replenishment frequencies are integer values. The second examined problem is the well-known Economic Lot Scheduling Problem (ELSP). The mathematical structure of this model is very similar that of the Joint Replenishment Problem. The last problem was the One-Depot Multi-Retailer Problem which can be modelled as a One-Depot One-Retailer Problem. This last problem is a united application of the first two models. The author of this paper has offered heuristics to calculate the optimal inventory holding policies on the basis of a Microsoft Excel side.

The presentations have demonstrated the borders of extensions of the classical Economic Order Quantity model. This simple management model can be very effective used to analyze very complicated business phenomena.

# Forecasting for Inventories

## AUGUST 24, 2010 ▸ F1

by John Boylan

There were three papers presented in the first session of the *Forecasting for Inventories* stream. The first paper, by *Adel Ghobbar and Justin Satink*, focussed on Maintenance, Repair and Overhaul (MRO) in the aviation industry. The demand for intermittent demand items is particularly difficult to forecast and the authors investigated the effect of combining several independent forecasts into a composite one. They examined spare parts for Fokker aeroplanes at Schipol and found that: i) only two forecasting methods need to be combined, ii) the best combination methods were regression, simple averaging and outperformance, iii) the best single methods were the Syntetos-Boylan Approximation (variation of Croston's method) and Single Exponential Smoothing.

The second paper, by *Georg Heinecke, Aris Syntetos and Wenbin Wang*, investigated exact and approximate solutions to demand classification. They compared two classification schemes, both of which determine whether it is preferable to use the Syntetos-Boylan Approximation or Croston's method for forecasting intermittent demand. The first scheme is approximate; the second scheme is exact. The comparison was based on a very large set of over 10,000 Stock-Keeping Units from the military, automotive and electronics sectors. The authors found that the percentage of SKUs that were correctly classified could be improved significantly by adopting the exact scheme. However, the improvement is forecast accuracy was much more modest.

The final paper, by *Seongmin Moon, Andrew Simpson and Christian Hicks*, examined classification models for predicting the performance of forecasting methods. Their application was for spare parts in the South Korean Navy. The navy's parts are characterised by extreme intermittence. In these situations, it may be beneficial to take advantage of the hierarchical structure of demand (e.g. product groups). The authors examined direct forecasting methods, hierarchical methods, and combinations of methods. By developing classification models using features such as the coefficient of variation of demand volume, it was possible to achieve consistent results across ten sets of data, thus producing good predictions of forecasting performance.

## AUGUST 26, 2010 ▸ F2

by Georg Heinecke

This was the final session of the 'Forecasting for Inventories' stream with a total of four scheduled presentations. The first presentation was held by John Boylan from Buckinghamshire New University in the United Kingdom. This was followed by two presentations by Jürgen Wöckl and Johannes Fichtinger, both from the WU Vienna. The final presentation was held by Bisheng Du from the Aarhus School of Business, Denmark.

The first presentation (*M. Zeid Babai, Mohammad Ali, Aris Syntetos, and John Boylan*) was titled '**Forecast Information Sharing in a Two-Stage Supply Chain with ARIMA(0,1,1) Demand**'. The aim of the research is to explore the forecasting and inventory implications of using different approaches to information sharing in a two level supply chain that consists of a retailer and a manufacturer when the retailer's demand process is ARIMA (0,1,1). Using empirical data from a major European superstore the findings suggest that information sharing can translate into error reductions and inventory cost savings.

The second presentation (*Jürgen Wöckl, Emel Arikan, and Johannes Fichtinger*) was titled '**Demand Forecasting for Single Period Risk-Averse Inventory Control and Pricing**'. The study presents and evaluates different approaches of including risk aversion within the process of demand forecasting

and inventory and price optimization. Accordingly the focus is put on the approach of estimating the demand distribution in a way that it fits with the attitude of a risk-averse decision maker. That is, a risk-neutral decision maker considers every random deviation from expectation with the same weight while a risk-averse decision maker would give the lower tail of the distribution more weight. The implications of the two scenarios are tested on empirical data from retailing companies against different performance measures (expected profit, profit variability, customer service levels, etc.).

The third presentation (*Emel Arikan and Johannes Fichtinger*) was titled '**An Empirical Study on Demand Models for a Price-Setting Newsvendor**'. The study considers price and inventory optimization in combination with three demand models: i) additive, ii) multiplicative and iii) a general demand model for which the authors suggest to estimate the demand distribution in a simple way which can cover different price-variance relations. The results suggest that the additive and multiplicative demand models do not differ significantly in terms of their operational performance, but using the general model can increase profit significantly.

The final presentation (*Bisheng Du, Christian Larsen, and Alan Scheller-Wolf*) was titled '**Advance Demand Information, Capacity Restrictions and Customer Prioritization**'. The study looked first at the case that permits buyers to place pre-orders before they observe their real demand and afterwards they have the possibility to issue additional orders as long as the supplier has sufficient capacity to meet them. For the case of a single buyer the problem is to estimate the impact on the order quantity. Now the authors introduce a scenario with a second buyer where both buyers have different priorities. The problem for this scenario is to examine the conjecture that the buyer with low priorities has to pre-order a larger quantity than the buyer with high priorities in order to receive the desired amounts of goods.

# Service Logistics

## AUGUST 23, 2010 ▸ S1

by Johan Marklund

The session was opened on time by the chairman. It included three presentations with the common denominator that they all considered spare parts inventory management and different types of inventory pooling. There were 25-30 people attending the session.

The first speaker was *Benhür Satir* from Cankaya University in Turkey, presenting a joint work with *Secil Savasaneri, and Yasemin Serin*, titled **Pooling through lateral transshipments in decentralized spare parts systems.** He described a continuous review inventory management problem for a service center operating in a decentralized service parts network. The considered center collaborates with another service center through inventory and service pooling, and through sharing information on the inventory status. The presented results included a characterization of the optimal operating policy of an individual service center, and a numerical investigation of different poling strategies and different levels of information sharing.

The second speaker was *Frank Karsten* from Eindhoven University of Technology in the Netherlands. He presented a joint work with *Marco Slikker and Geert-Jan van Houtum* titled **Spare parts inventory pooling games.** The presented work deals with situations where several independent companies stock a given spare part and contemplate collaboration by pooling their inventories. A cooperative cost game was defined and the conditions under which such a game has a nonempty core, i.e. a stable cost allocation exists, were specified. For identical, companies it was proven that the core of the associated game is always non-empty. These results were then generalized by proving core non-emptiness for situations allowing companies to have non-identical demand rates and base stock levels and for situations allowing companies to have non-identical downtime costs.

The third and last speaker in the session was *Willem van Jaarsveld* from Erasmus University Rotterdam, in the Netherlands. He presented a joint work with *Rommert Dekker* titled **Integrating reliability centered maintenance and spare parts stock control.** A difficulty with in applying the classical inventory models in practice is the estimation of shortage costs or the determination of appropriate minimum fill rates. The talk presented one possible way to overcome this problem, by using data gathered in reliability centered maintenance studies to determine shortage costs. Benefits of the approach as well as complications were thoroughly discussed. A modeling framework and an analytic method to determine minimum stock quantities in case of redundancy and multiple systems were presented. It was also shown that including redundancy information in the stocking decision renders significant cost benefits.

The session was closed on time after a short discussion among the attendees.

## AUGUST 23, 2010 ▸ S2

**A Simple Algorithm to Determine Optimal Base Stock Levels in a Two-Echelon Spare Parts Network,**
*R. Basten, G.-J. Van Houtum*
This presentation considered a two-echelon inventory system with low demand. All sites apply continuous review (S-1, S) ordering policies. Different techniques for evaluation of a certain policy have been considered in several papers. However, this paper focuses on the optimization process. The authors have developed a very fast and efficient optimization technique. At this stage it has not been possible to prove that the technique will always provide the optimal solution.

**Periodic-Review (S, T) Policies for Distribution Systems with Multiple Retailers and Stochastic Demand**
*Q. Wang, S. Axsäter*
This paper considers a distribution system consisting of a central warehouse and a group of retailers

facing independent stochastic demand. The retailers replenish from the warehouse, and the warehouse from an outside supplier with ample supply. Time is continuous. Most previous studies on inventory control policies for this system have considered stock-based batch-ordering policies. In this study a time-based alternative policy is suggested. The warehouse uses a basic replenishment interval. The retailers are replenished through the warehouse in intervals that are integer multiples of the basic replenishment period. No inventory is carried at the warehouse. Although it is well-known that stock-based control policies dominate time-based control policies at a single facility, this dominance does not hold for distribution systems with multiple retailers and stochastic demand. This and other findings may be useful when analyzing multi-echelon inventory systems.

**Condition-Based Maintenance Policies Under Delay Times for Failures**

*G.-J. van Houtum, D. Celebi, A. M. H. Elwany*

This presentation dealt with condition-based maintenance policies for critical components of technical systems. A component can be functioning well as well as in a failure state. In addition the authors consider a defective state, where a component can be during a few days or a week. The idea is to perform maintenance action when the component is in a defective state. The paper develops cost expressions for such condition-based maintenance policies. Using the cost expressions the inspection intervals can be optimized. The study provides various analytical results as well as numerical results.

## AUGUST 24, 2010 ▸ S3

by Kurtuluş Barış Öner

The session started at 14.00 with an audience of about 35 people.

The first speaker, *Morteza Pourakbar*, gave a talk about a final order problem in which remanufacturing is also considered. They consider a manufacturer who is responsible for provision of spare parts of a capital good throughout a service contract period. The production of the parts terminates before the service contract expires and the manufacturer has to place a final order at the termination time to cover the demand until the end of the service contract period. The demand can also be met by remanufacturing and using phased-out returns from the field. They investigate a number of policies and find the optimal final order quantity and remanufacturing policies.

The second speaker, *Thomas Yeung*, presented a study on a maintenance and replacement decision problem. They consider a system which is bought with a number of spare parts initially. During the exploitation phase of the system, improved versions of the system might be introduced to the market. The improvement can be in terms of reliability and/or throughput. The user has to decide whether to keep the system as it is, repair it (by using one of the spare parts) or replace it with an improved one periodically. They model the problem as a Markov decision process and derive insights about the optimality of the decisions.

The last presenter, *Kurtuluş Barış Öner*, presented a talk about redundancy optimization for critical components in a capital good. They consider a user who buys a number of identical systems. The user may choose to build in cold standby redundancy for critical components in the system. She also buys spare parts with the systems and keeps spare parts inventory during the whole exploitation phase. When a part in a system fails during the exploitation phase, the failed part is replaced by a ready-for-use one from the spare parts inventory. A part is shipped from a distant central warehouse upon stock-out events. They formulate the problem as the minimization of the total costs incurred for the systems under a constraint for the total uptime. They derive results on the optimality of redundancy per component.

Each talk provoked a discussion afterwards. The discussions took about 4 minutes per talk and the session ended about 4 minutes later than the planned time. There was a circulation of the audience among different sessions, but the number of the people remained about 35 throughout this session.

## AUGUST 24, 2010 ▸ S4

by Sean Zhou

We had three presentations in this service logistics session. All of them were closely related to the service logistics theme. All three talks were well received and quite some questions were asked by the audience. So overall I think the session ran very well and was quite successful. I briefly summarize the three presentations in the following:

The first presentation is given by *Maarten Drisessen* from Technical University of Eindhoven titled "**Decision Framework for Spare Parts Management in an MRO Organization".** In this talk Maarten proposed a framework for strategic, tactical and operational decisions in spare parts management. He further discussed how this framework can be applied in different companies

*Agostino Bruzzone* from University of Genova gave the second presentation titled **"Pool Based Scheduling and Inventory Optimisation for Service in Complex System".** He proposed a methodology based on integration of optimization and simulation for supporting complex systems like power plants.

The third presentation was given by *Sean Zhou* (myself) from the Chinese University of Hong Kong. The title is **"Spare Parts Management with Dual Supply Sources and Two Demand Classes".** In this talk, a spare part inventory model with dual sourcing and two demand classes is introduced and a class of inventory replenishment and demand rationing policies is analyzed Sean also shows the numerical performance of the policies.

## AUGUST 26, 2010 ▸ S5

by Simone Zanoni

Three papers were scheduled for this session on Service Logistics.
The first paper in this session, "**A Classification of Joint Maintenance and Inventory Optimization Models**", written by *Jasmine Buré, Dirk Cattrysse and Pieter Vansteenwegen* was presented by Jasmine Buré. They have studied the existent literature on jointly optimization of spare parts and maintenance considering the trade-off between maintenance and inventory policies. The first aim of the paper is to present a survey on this topic with the classification of the relevant literature. The review is the starting point of research on the mobile repairman problem, a special case of after sales service management. Thus, the second part of the presentation was focused on a specific context for jointly optimization of spare parts and maintenance: the case presented refers to a service company that have to travel to their customers to repair the broken machines . So as to tackle this problem some scheduling and routing aspects have been considered into the model proposed.

The second paper, entitled "**Optimal Inventory Control of Manufacturing/Remanufacturing Systems With Quality Grading**" by *Morteza Pourakbar, Saif Benjaafar, Mohsen Elhafsi and Rommert Dekker* was presented by Morteza Pourakbar. The study consists in the evaluation of the optimal policy structure for a manufacturing/remanufacturing system where the returned items may have different quality grades. Three different models were presented on the basis of different assumptions: the first one considers remanufactured items as good as new, the second one considers remanufactured items differentiated from manufactured, the third model assumes differentiated customers into high and low priority class customers. Results of a numerical analysis presented demonstrate the performance of the state dependent policies proposed for the three different models and highlight the role of quality grading in hybrid systems.

The final paper entitled "**Hybrid Lateral Transhipments in a Multi-Location Inventory System**" by *Ruud Teunter, Colin Paterson and Kevin Glazebrook* was presented by Ruud Teunter. They propose a new transhipment policy for inventory pooling in managing networks of stock holding locations. The traditional reactive transhipment policy have been enhanced incorporating a proactive element: the proposed hybrid transhipment policy allows to transhipment more stock than is needed to meet the immediate shortage, this permits the two locations which are parties to a transhipment to redistribute their stock and balance

future risk. Presented results of numerical studies which utilise dynamic programming and simulation, showed that in comparison to a purely reactive approach to transhipment, service levels are improved while a reduction in safety stock levels is achieved. Moreover the aggregate costs incurred in managing the system are significantly reduced, especially for large networks facing high levels of demand.
The three presentations were attended by around 20 people. After each presentation, comments and questions were solicited from the audience with an helpful purpose.

## AUGUST 26, 2010 ▸ S6

by Refik Güllü

The first paper in this session, "**The Use of Selective Emergency Shipments for Fulfilment of Differentiated Servive Contracts for Capital Goods**", was presented by *Elisa Alvarez* (co-authored with Matthieu van der Heijden and Henk Zijm). Alvarez argued that the "one-size-fits-all" approach in service contract fulfilment or reserving spare parts for premium customers are not suitable in most of the situations. Instead of these alternatives, Alvarez proposed a policy which uses selective use of emergency shipments based on the characteristics of parts and the customer class. Elisa Alvarez presented a mathematical model, based on Dantzig-Wolfe decomposition, that aims minimization of system costs while trying to satisfy mean waiting time constraints for customer classes.

The second paper, titled "**On the Use of Install-Base Information for Spare Parts Inventory Control**", is presented by *Rommert Dekker* (co-authored with Cerag Pince). Romert Dekker proposed forecasting spare parts demand by forecasting the install-base, rather than using historical data of spare parts demand. Dekker presented several case studies, and gave a comparison of install-base forecasting with time series forecasting, based on a simulation study. Next, Romert Dekker discussed specific instances where an install-base forecasting can be suitably used.

The last paper of the session, **"A Model for Performance Evaluation and Stock Optimization in a Kit Management Problem"** was presented by *Refik Güllü* (co-authored with Murat Koksalan). Refik Güllü motivated the problem by presenting a medical application. Then, he presented the mathematical model where customer demand occurs for kits, rather than individual items. Refik Güllü discussed various properties of the model and presented a closed form expression for the "kit-readiness" probability. Then, he formulated an optimization model which minimizes long-run expected system costs under "kit-readiness" constraints, and proposed a heuristic algorithm for the solution.

## AUGUST 27, 2010 ▸ S7

by Matthieu van der Heijden

In this session, we had three very interesting presentations: one on the bullwhip effect in the retail sector and two presentations in the area of service logistics. The latter two presentations were closely related, because they considered in a certain sense the cost reduction that can be obtained by intelligent variation of repair throughput times of repairable spare parts for maintenance of advanced capital goods.

*Harold Tiemessen* presented a joint paper with Geert-Jan van Houtum on reducing costs of spare parts supply systems via dynamic priorities. They study a system consisting of one repair shop and one stockpoint where spare parts of multiple, critical repairables are kept on stock to serve an installed base of technical systems. Demands for ready-for-use parts occur according to Poisson processes, and are accompanied by returns of failed parts. The demands are met from stock if possible, and otherwise they are backordered and filled as soon as the repair shop has a ready-for-use item available. The study focuses on operational control, i.e., the spare part stock levels have been optimized at a tactical level taking into account finite repair capacity and (static) repair priorities per item. Given these spare part stock levels, the static priorities are removed and replaced by a dynamic, state dependent priority rule. The authors show that significant gains are possible using dynamic

priorities, about 10% compared to the solution with static priorities (and much more if no priorities are taken into account at all).

Whereas Tiemessen and van Houtum considered priorities at an *operational* level, *Van der Heijden* focused on the tactical level in a joint paper with Elisa Alvarez and Marco Schutten. They also focus on influencing repair throughput times in spare part networks, but consider the joint trade-off between spare part stock levels and repair- and transportation throughput times in general multi-echelon, multi-indenture networks. They do not consider finite repair capacities (as Tiemessen and van Houtum), but assume that various options for the repair and transportation throughput times may be selected at different costs. Such a model may be applicable if repair capacities are fuzzy (e.g. because the service engineers have other tasks next to spare part repair) or even unknown (in case of outsourcing of repair). They use a greedy heuristic for the trade-off and find an average cost reduction of 20% compared to the use of standard throughput times in a large experiment for two-echelon, two-indenture networks. They also apply their approach to a case study at Thales Netherlands, namely radar system. There they find considerably less cost savings, which is mainly due to the fact that the options for throughput time reduction are limited in the case study. In fact, only throughput time reductions upstream in the service supply chain are feasible, whereas the numerical experiment shows that throughput time reductions downstream in the supply chain are most profitable. The platter holds in particular for items high in the product structure (modules).

The presentation in between by *Giulio Zotteri* gave interesting insights in the bullwhip effect in actual retail supply chains. He conducted an empirical study in Italy on this bullwhip effect with special attention for the so-called "End-of-Period-Effect". This is the effect of the end of a period (e.g., year) on the variations of demand and performance. Giulio Zotteri discussed how the end-of-period-effect might create a bullwhip effect, based on data of an Italian subsidiary of a multi-national company that operates in 130 countries. He focuses on nine types of fast moving consumer goods, at a week level and over a period of 52 weeks, where demand is recorded both at retail and wholesale level. He shows that the bullwhip, as measured by the ration of coefficients of variation in the upstream and downstream stage of the supply chain, changes significantly (the range is 0.95 to 3.95). This suggests that demand variability upstream in the supply chain can be much greater than the downstream one in some cases (3.95) but it can be even (slightly) more stable than downstream demand (ratio of CVs equal to 0.95). For products with a very seasonal consumer demand, the bullwhip effect seems to be negligible (e.g. solar creams). On the contrary, for products with a relatively stable demand a rather significant increase in demand variability in the upstream stage of the supply chain is observed. A question addressed the issue whether this observation would change if the bullwhip effect is corrected for seasonal demand forecasting. This is a topic for further research.

## AUGUST 26, 2010 ▸ S8

by Ruud Teunter

In this session, two papers dealing with applications of multi-echelon spare parts inventory management were presented. *Guangyuan Yang*, Erasmus University Rotterdam, The Netherlands, presented the paper "**Service Parts Inventory Control with Lateral Transshipment that Takes Time**" co-authored by Rommert Dekker. An approach for setting target inventory levels in a multi-echelon system with a central and multiple regional warehouses with transshipments was presented and illustrated using a real world case that illustrates the benefits of using transshipments and explicitly required the modeling of non-negligible transshipment times.

The second paper **"Spare Parts Optimization in Airport Equipment Maintenance"** was presented by *Dario Pacciarelli*, Roma Tre University, Italy, co-authored by Annalisa Cesaro. Using a case for 38 civil Italian airports, an inventory pooling approach was presented that requests spare parts from a warehouse, nearby warehouses, or an external supplier. The problem was formulated as a non-linear integer programming problem for allocating spares to warehouses and a branch-and-bound as well as a tailored heuristic were developed and benchmarked.

# Risk Management in Supply Chain Inventory Systems

## AUGUST 23, 2010 ▸ R1

by Hajnalka Vaagen

Classical analytical inventory models offer a variety of insights into the optimal way to manage inventories of individual products. However, top managers and industrials are often concerned with the aggregate macroscopic view of a firm's inventory rather than the inventories of individual products. Given that classical inventory models often do not account for many practical considerations that a company's management faces (e.g. competition, industry dynamics, business cycle, the financial state of the company and of the economy) and that they are derived at product level and not at firm level, can insights from these models be used to explain the inventory dynamics of entire companies?

Further, supply chain risk management acknowledges that most potentially important decisions are to be taken in light of uncertainty; particularly, uncertainty in customer demand. Supply chain models that do not account for potentially important risk factors, might lead to decisions that do not reflect the problem complexity. As a consequence, supply chain disruptions can generate increased inventories as buffer for disruptions and increased costs. Risk management practices, techniques and tools have been used extensively in the financial community for years. However, these are not yet common in production and inventory planning. The above acknowledgements led researchers in recent years to focus on organizational and supply chain related issues, and risk in inventory systems.

The three papers presented in this session are different initiatives to manage supply chain risks by applying financial instruments, by means of production/inventory strategies, introducing new factors that are ought to be accounted for in inventory models, and product portfolio strategies.

The paper **"Transfer of newsvendor inventory and supply risks to sub-industry and the public by financial instruments"**, by *Yick Hin Hung, Leon Li and T.C.E. Cheng,* discusses the option of reserved production capacity (called 'super capacity') to reduce mismatch costs –stockout and markdowns–, and hedge against demand uncertainty between retailers, their suppliers. The authors provide a single-item two-stage analytical formulation, where in stage one the retailers buy physical goods for an initial inventory and protective capacity in terms of futures and options on futures. In stage two, after demand realisation, required protective capacity is converted into inventory, and the residual capacity is exchanged among supply chains by cooperative gaming. Underlying assumption in this work is short supplier lead times, to enable quick response after demand uncertainty is revealed.

In the paper "**Parameter determination for production/inventory control in the case of stochastic demand and different type of yield randomness"**, *Karl Inderfurth and Stephanie Vogelgesang* introduces yield randomness, as a new factor that ought to be accounted for in inventory systems where not only customer demand is stochastic, but also production is exposed to stochastic yield. The authors provide parameter determination approaches to binomial and interrupted geometric yield distribution.

**"Measuring the Risk in Substitutable Newsvendor Models"**, by *Hajnalka Vaagen, Stein W. Wallace and Michal Kaut*, treats the inventory management problem from a different angle, by studying the operational risk of a particular product line, where the items are each others' partial substitutes and competitors. The authors provide a stochastic programming formulation of the multi-item substitutable newsvendor risk problem, by combining the substitutable newsvendor from operations and the mean-variance Markowitz model from finance. The aim is to provide insights into the structure of an optimal product line (items

to be included and their inventory levels) for a given profit risk to be taken. The choice of stochastic programming as methodology, for a problem traditionally studied by analytical formulations, is reasoned by the recognition that analytical formulations provide great insights, but cannot handle the complexity of dependencies and complex demand uncertainty structures (bi-modal distributions here).

## AUGUST 24, 2010 ▸ R2

by Hui Ming Wee

There were 3 presenters in this session. The first speaker was *Jury Gualandris* whose topic was **"An Assessment Model to Evaluate Supply Chain Resiliency: Application in the Assembly Industry"**. The talk was interesting, though there was very little discussion.

The second presentation was done by me on "Vendor Buyer Inventory Models with Discrete Delivery Order, Random Machine Unavailability and Lost Sales". There were some discussions where Prof. Jaber and Prof. Banerjee suggested some improvements and references to add.

The final paper was presented by PC Yang who did a good job to discuss the "Collaboration for a Closed-loop Deteriorating Inventory Supply Chain with Multi-retailer and Price-sensitive Demand". We have an interesting discussion on the paper.
Overall, the session went quite well with good number of conferees attending the session. Thank you to the organizers for a well organized conference.

# Inventory and the Environment

## AUGUST 26, 2010 ▸ E1

by Maurice Bonney

Session E1 was the first of two sessions that formed the Inventory and the Environment stream of the Symposium. The stream was fortunate that in the plenary session on Monday 23 August, Henk Zijm had presented a paper entitled 'Challenges facing inventory researchers' which gave a very interesting and balanced view of environmental problems and some of the questions that they pose for inventory researchers. That was just the introduction that Session E1 needed to set the problems discussed in an appropriate strategic context.

Session E1 had three presentations.

**Consignment stock for a two level supply chain with entropy cost**
*Mohamad Jaber - Simone Zanoni – Lucio Zavanella*

Coordinating order quantities is an important problem in a supply chain. This paper discussed a standard problem related to 'consignment stock' (where a buyer's inventory is managed by the vendor) and then applied entropy cost ideas to the problem. A consignment stock policy usually reduces the cost of the vendor's inventory because the stock is held at the buyer's store. In return the vendor can better supply the buyers demand and the buyer's stock is only paid for when it is withdrawn from inventory.
The entropy cost concept was used to represent the hidden costs in inventory and production systems including system disorder and the paper applied the second law of thermodynamics to reduce the entropy cost of the supply chain with the hope that this would improve the system environmental performance.

**Investigating City Logistics: an empirical study from Piedmont**
*Giulio Zotteri*

This rather inspirational paper described some of the transportation problems of logistics in the Piedmont region in Italy. The city needs goods but the distribution of goods affects air pollution, traffic congestion, is noisy, etc. Can city logistics systems be designed so as to reduce the environmental impact of distributing goods?

The data was obtained by means of surveys. Some 1500 interviews were conducted to investigate both the demand and the supply side of the distribution services. Specific results from the surveys were that:

- A significant amount of the flow in a city originates in the city itself and so the use of public distribution centres on the city's outskirts may not be very effective in large cities
- The use of time windows is a commonly used way to reduce traffic. Unfortunately, time windows can concentrate traffic into certain hours and can increase rather than reduce congestion
- Time saturation (only a certain time is available for travel and deliveries) is an important issue. This means that distance between points of delivery and speed in the city can have both environmental and economic effects e.g. trucks may not be fully loaded.

**Environmental and Economic Analysis of a Production-inventory System and its attributes using an input-output Activity Matrix**
*Maurice Bonney – Mohamad Jaber*

In this paper, the authors attempted to represent by means of an Activity matrix the activities in a supply chain that includes a manufacturing system. The Activity Matrix was developed in the form of an input-output matrix with the aim of allowing input-output ideas to be applied to improve both the environmental and the economic performance of supply chains.
To obtain the system activities the manufacturing system was considered as a concurrent enterprise and then the ideas of structured analysis were used.
By adding further flexibility to the Activity Matrix the representation may be used as a systems design tool.

## AUGUST 26, 2010 ▸ E2

by Mohamad Y. Jaber

Four papers were presented in this session. There were about 20 attendees. A summary and comments on these papers are presented below.

**The economic and environmental sustainability of dual sourcing**
*Heidrun Rosic and Werner Jammernegg*

This paper suggested a transport-focused dual sourcing framework. They argued that based on economic performance measures different supply chain strategies turned out to be advantageous. However, more transport and negative environmental impact. Companies had to re-evaluate and reconsider strategies. To address this concern, they raised two research questions: (1) how does a dual sourcing strategy perform with respect to economic and environmental sustainability focusing on the related transport activity? and (2) what is the impact of environmental regulations for transport on the decision?

They considered two sources of supply (offshore and onshore) and wanted to determine how much to order from which source. To answer this question, the introduced external conditions (environmental regulations for transport) to the system; linear emission tax and emission trading. The mathematical model they developed was solved restricting the order quantity (a decision variable) between upper and lower limits. There results showed that when introducing these limits it is recommended to order in smaller lots than the basic classical model; i.e. the one with no constraints. As the emission cost increased the optimal policy was to order more from onshore and less from offshore. The profit decreased linearly as a result. Their results also should that there exists an optimal order quantity to which profit is maximized. They showed that profit decreased as the emission limit decreased, and increased otherwise.

The authors concluded that dual sourcing helps to reduce negative environmental impact as transport emission tax helps to reduce the transport activity, but harms the economic performance of companies. They suggested that emission limit should be adapted to the economic situation.

In my opinion, the paper raises an important issue about logistics as being the element of the chain that contributes the most to the $CO_2$ emissions. The paper falls short on discussing how introducing these emission limits affect globalization as they are advocating ordering more from onshore suppliers as the environmental cost increases. Their model is based on the assumption that non-renewable energy will remain to be the "only" source of energy that keeps our logistics moving. I think we ought to start discussing how shifting into modes of transportation that use renewable energies or technologies that reduce emissions. Another limitation to this work is the assumption that items imported are all of good quality. This is not true as many overseas shipments contain defective items that are disposed off at an additional cost to the environment.

**Energy implications in Lot Sizing**
*Simone Zanoni and Lucio Zavanella*

This paper suggests adding a third cost component that measures the consumption of energy required to produce a certain batch to the classical economic order quantity (EOQ) model. They have done a good job in supporting their assumption/idea by providing a reasonably good background to the increasing trend in energy consumption, the targets set by EU countries to reduce energy wasted and reduce emissions that greenhouse gases. They noted that most of the energy is consumed even while the machine is ''idling'' and that much of this energy is related to the pumping of coolants, lubricants, and hydraulic fluids that are later treated as wastes. This was supported by study of the Toyota manufacturing processes.
In their paper, they developed a cost component that is in line with the findings in the literature. Then they modified the EOQ model by optimizing the sum of two traditional costs (setup/order and holding) and the energy cost. The optimal production quantity was found to be the same as that of the

EOQ; however, they found an optimal production rate that minimizes energy waste and subsequently emissions. This is inline of the literature that discuss the advantages of varying the production rate. Later, the authors put their model to the test by investigating two-level supply chain model with two different coordination mechanisms (traditional and consignment stock policies). In their numerical analyses, the authors presented a case study from plastic injection moulding. They concluded that energy implications should be carefully considered while performing lot-sizing decision with variable production rates and showed how energy costs significantly impact on the total costs at different production rates. As a future work, the authors suggested (1) performing numerical analyses in different sectors, (2) to consider energy components in set-up and holding, and (3) to refine the concept of "energy use at idle state" with respect to the production context (e.g., process and intermittent manufacturing)

I found this paper to be "very" interesting as it opens the door wide for many inventory models to be revisited and investigated for energy costs. The model is also interesting as it could be easily used to investigate the impact of technology transitions from conventional to non-renewable. In their model, the authors assumed that the lots are independent of the lot size. It is worth investigating otherwise.

**How many times to remanufacture?**

*Ahmed M.A. El Saadany, Mohamad Y. Jaber, Maurice Bonney*

This paper extends the earlier work on the production, remanufacturing and waste disposal model (in particular the work of Richter and Dobos), which assume that an item can be recovered (remanufacturing/repaired/recycled) indefinitely, by introducing an assumption that is more realistic and technologically feasible where an item can be recovered for a limited number of times. They showed that the assumption of indefinite recovery underestimates the costs. Later, they modified the model of Richter (International Journal of Production Economics, 45 (1-3), 443-447 1996) by introducing (1) a design cost function and replacing (2) the constant reparable rate (Richter et al.) by one which is a function of the number of the time an items can be recovered. Their design investment cost function was assumed to be a function of the number of times an item can be recovered. Their results showed that there is an optimal number of remanufacturing generations that balances investment costs with remanufacturing costs. Their results also suggested that assuming unlimited remanufacturing presents misleading results that may not capture the benefits that product recovery programs are supposed to bring.

I cannot comment on this paper as I am one its authors.

**Corporate Social Responsibility and Inventory Policy**

*Lucía Barcos, Alicia Barroso, Jordi Surroca, Josep A. Tribó*

This paper studies the relationship between corporate social responsibility (CSR) and inventory levels. This paper also studies whether improvements in the satisfaction of employees, customers, and natural environment interests increase, reduce or do not affect inventory volume. What is of interest to this session is how environmental policies affect inventories. Two types of environmental policies were considered: (1) compliance, and (2) pollution prevention. They hypothesized that reducing waste and pollution generated from components and parts may be achieved by working with lower inventory levels. They also hypothesized that a firm's social responsible behaviour have a curvilinear (inverted U-shape) relationship with inventory investment. They developed a regression model taking advantage of the panel data structure of the sample. Their results show that improvements in the satisfaction of employees, customers and natural environment have different effects on inventories, and also describe a natural stabilizing mechanism that may smooth the economic cycle.

In my opinion, the relevance of this paper to the session was not very clear. It brought up some discussion amongst the audiences. Some critiqued the work other welcomed it.

## AUGUST 26, 2010 ▸ E3

**The Effect of Inventory Investment on Ecological Footprint**

*Mária Csutora, Imre Dobos,*
Corvinus University of Budapest, Hungary

The Leontief input-output model is widely used to determine of the ecological footprint of a region or a country. These studies are static and the dynamic investigations are neglected. The dynamic Leontief model makes it possible to involve the capital and inventory investment in the footprint calculation. A new calculation method is shown to determine the effect of capital accumulation on ecological footprint. The proposed method is demonstrated on the Hungarian dynamic input-output model.

**Optimal Pricing and Production Planning Decisions in Reusable Container Systems**

*Büsra Atamer, Ismail Bakal, Pelin Bayindir*
Middle East Technical University, Turkey

The main objective of the study is to focus on the decision making problems in reusable container systems with stochastic demand. Optimal pricing and production planning decisions in reusable container systems result in more profitable and environmental-friendly production alternatives for manufacturers and cheaper products for consumers. One typical example of reusable container systems is a beverage production system using refillable bottles. Customers purchase the products within reusable containers and then may return the container to the producer in consideration of a deposit price. The return amount is neither constant nor deterministic; it depends on both customer demand and the deposit price determined by the producer. Hence, the manufacturer has the opportunity to manipulate the return quantity via the deposit price. Since only a proportion of the containers will be returned throughout the period, the producer also has to decide on the quantity of brand new reusable containers to be purchased. The unit cost of production with a new reusable container is different from the unit cost of refilling a returned container when collection and set up costs are taken into account. Also, there may be a capacity restriction on the manufacturing and remanufacturing operations. That is, production planning and pricing decisions are to be made simultaneously for a synchronized reusable container system. This approach utilizes constrained non-linear optimization techniques. The study is completed with the investigation of the model analytically and computationally. The analytical and computational results show that, the unit profit margins of different production alternatives are not adequate in indicating the most profitable pricing and production planning option; but an overall view to the reusable container system is required.

# Implementation of Inventory Management Theories and Models in Organizations

## AUGUST 23, 2010 ▸ MO1

by Ram Ganeshan

We had three very interesting papers presented in this session all related to how process improvement and effective inventory management can significantly impact organizational performance.

The first paper, **"Hybrid Contracting Within Multi-location Networks"** by *Alexander Dobhan and Michael Oberlaender* dealt with hybrid contracting within a multi-echelon network. A hybrid contracting process would allow decentralized units in an organization to make operational plans independently, but within bounds that are set by a central planner. The findings indicate that the hybrid approach improves contracting results even if the cost parameters of each decentralized site is not shared between units.

The second paper **"A Model to Explore Free-shipping Policies of Online Retailers"** by *Ram Ganeshan and Tonya Boone* explored free shipping policies of online retailers. Free shipping will attract customers, but is also expensive to operate! A model, based on the authors' experiences with online retailers, was presented that evaluated the various trade-offs involved in free-shipping promotions. A key insight was that online retailers do best when (a) they have a qualified free-shipping promotion (for example "free shipping of orders over $150"), and (b) by using a model to determine a threshold beyond which to offer the free shipping.

The final paper, **"Process Performance Improvement in Justice Organizations - the Pitfalls of Performance Measurement"** by *Petri Niemi and Petra Pekkanen* talked about an interesting partnership between Lappeenranta University and the Finnish Department of Justice that explored how to address that the highly variable and often long lead times on cases. One major insight of the paper was that certain operational efficiency measures may lead to unwanted effects like distortions in case flow prolonging the lead time. The authors explored how simple yet powerful performance measures coupled with process improvement vastly improved case flow times.

Overall the three papers gave a good overview of how inventory management and operational efficiency theories can be implemented in manufacturing or professional service settings. It is the Chair's view that the 20+ colleagues who attended these talks enjoyed them!

## AUGUST 24, 2010 ▸ MO2

by Janne Huiskonen

*Petri Niemi and Marianna Purhonen:* **A knowledge based approach for crafting a strategic SCM development program – a case study**
In the first presentation Petri Niemi presented a framework for developing a strategic SCM development program for a company. It aims at facilitating change in the area of SCM development. The approach was based on combining earlier research on knowledge maturity models and generic knowledge development strategies, and dividing development area into four major areas: 1) organization and responsibilities, 2) knowledge and skills, 3) data processing systems, and 4) performance measurement and incentives. The approach had been tested during a development program process of a multinational manufacturing company.

*Judit Nagy:* **Role of VMI in managing supply chain**
In the second presentation Judit Nagy presented results of a survey and case studies on the use of different supply chain techniques in Hungarian companies focusing especially on the spread of VMI. The study found out success factors and pitfalls of VMI. As main findings were that efficiency of VMI depends on the long-term view and intention of parties to trust each other. The intensity and quality of shared information have a key role in successful implementation.

*J. Jonrinaldi and David Zhang:* **Coordinating production and inventory control in a whole green manufacturing supply chain network**
In the third presentation J. Jonrinaldi presented a model to optimize a supply network from 2-tier supplier through 1-tier suppliers, manufacturer, multiple distributors, retailers, and finally third party collector for used finished products. The model was stated as a mixed integer non-linear programming model and it was illustrated through an example problem. The model assumed a policy which can be followed in the whole network to optimize the whole system's annual total costs. In the followed discussion a question was raised whether a game theory approach could be used to model the behavior of the individual parties of the network.

## AUGUST 23, 2010 ▸ MO3

by John Kanet

In this session attended by approximately 15 people, two papers were presented.

"**Inventory Performance of Work Flow Control Methods in Make-to-Order Job Shops**"
*Steven Harrod, John Kanet*, both of School of Business, University of Dayton, USA

In this paper, the authors measured the inventory implications of employing three alternative methods for limiting work in progress (WIP) in a simulation of a make-to-order randomly routed job shop operating under a priority dispatching regime of shortest operation processing time first. The methods evaluated included Kanban, CONWIP, and POLCA . After creating a simulation of a balanced five machine shop operating at 80% utilization with uniformly distributed random job routings, inventory performance according to the system partition: ready jobs, jobs in process, and finished jobs was reported. One of the main conclusions was that flow control approaches do in fact reduce the number of jobs in process but total system inventory increases.

"**Exploring the Economic Consequences of Paying a Supplier to Keep a Reserve Inventory**"
*Soheil Abginehchi, Christian Larsen, and Anders Thorstenson*, all of Centre for Research Applications in Logistics (CORAL), Aarhus School of Business (ASB), Aarhus University, Denmark)

This work was inspired by a contact with a larger telecommunication company whose unique products have very short lifetimes (approximately 18 months). The suppliers do not wish to hold any inventory and only accept orders on a periodic basis, most often once per month. Additionally lead times are very long as suppliers are located overseas. The company seeks to negotiate a contract with the supplier in which a reserve inventory is held locally (to the firm) for a higher price but also with shorter lead time. The problem is modeled as a two supplier inventory model. A dynamic programming formulation is used to assess the economic impact of such an arrangement.