International Society for Inventory Research

10th Summer School on

"Emerging Trends in Inventory Modeling for Service and Manufacturing"

List of Participants, Program and Abstracts

August 22-26, 2011

Boğaziçi University, Industrial Engineering Department

Istanbul, Turkey

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10th ISIR Summer School

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10th ISIR Summer School
Schedule

		Monday, August 22	Tuesday, August 23	Wednesday, August 24	Thursday, August 25	Friday, August 26
9:00 AM	**9:10 AM**	Welcome: Refik Güllü and Louis Maccini				
9:10 AM	**9:30 AM**	Opening: Henk Zijm				
9:30 AM	**10:25 AM**	Stephanie Vogelgesang	Ece Zeliha Demirci		Kristel M.R. Hoen	M. Güray Güler
10:30 AM	**11:25 AM**	Josephine Clemens	Maximiliano Udenio		Laura Bettoni	Olle Stenius
11:30 AM	**12:00 AM**	Coffee Break	Coffee Break	Factory Excursion and Tour of Topkapi Palace and Basilica Cistern	Coffee Break	Coffee Break
12:00 PM	**12:40 PM**	Nesim Erkip	Ou Tang		Oben Ceryan	Murat Kaya
12:45 PM	**2:00 PM**	Lunch	Lunch		Lunch	Closing: Attila Chikàn
2:00 PM	**2:55 PM**	A.C.C. van Wijk	Guangyuan Yang		Laura Mazzoldi	
3:00 PM	**3:55 PM**	Arkadi Seidscher	Yannick Deflem		Mustafa Hekimoğlu	
3:55 PM	**4:25 PM**	Coffee Break	Coffee Break		Coffee Break	
4:25 PM	**5:20 PM**	Willem van Jaarsveld	Mario Guajardo		Danijel Kovacic	
5:25 PM	**6:05 PM**	Stefan Minner	Geert-Jan van Houtum		Zsolt Matyusz	
6:30 PM	**8:00 PM**	Coctail Prolonge	Summer School Dinner			
8:00 PM	**10:00 PM**					

10th ISIR Summer School Program

Monday - 22.08.2011

09:00 AM	**09:10 AM**	Welcome to Summer School: *Refik Güllü and Louis Maccini*
09:10 AM	**09:30 AM**	Opening Remarks*: Henk Zijm*
09:30 AM	**10:25 AM**	Karl Inderfurth and *Stephanie Vogelgesang:* **"Demand and Yield Risks in Production Systems – Testing the Quality of Linear Order Rules Via Simulation"**
10:30 AM	**11:25 AM**	Karl Inderfurth and *Josephine Clemens* **"Analysis of the Supply Chain Coordination Potential of Different Contracts Under Random Production Yield"**
11:30 AM	**12:00 AM**	Coffee Break
12:00 PM	**12:40 PM**	*Nesim Erkip* **Spare Part Management: A Life-Cycle Approach**
12:45 PM	**02:00 PM**	Lunch
02:00 PM	**02:55 PM**	*Sandra van Wijk*, G.J. van Houtum and I.J.B.F. Adan **"Lateral Transshipments in Spare Parts Inventory Models"**
03:00 PM	**03:55 PM**	*Arkadi Seidscher* and Stefan Minner **"A Semi-Markov Decision Problem For Proactive and Reactive Transshipments Between Multiple Warehouses"**
03:55 PM	**04:25 PM**	Coffee Break
04:25 PM	**05:20 PM**	*Willem van Jaarsveld* and Twan Dollevoet **"Spare Part Inventory Control For a Component Repair Shop"**
05:25 PM	**06:05 PM**	*Stefan Minner* **"Publication of Inventory Research in Operations Research/Management Science Journals – An Author's, Editor's, and Referee's Perspective"**
06:30 PM	**08:00 PM**	Coctail Prolonge

Tuesday - 23.08.2011

09:30 AM	**10:25 AM**	*Ece Zeliha Demirci* and Nesim Erkip **"Optimal Incentive Design For Public-Interest Goods"**
10:30 AM	**11:25 AM**	*Maximiliano Udenio*, Jan C. Fransoo and Robert Peels **"Sales Forecasting During the Credit Crisis"**
11:30 AM	**12:00 AM**	Coffee Break
12:00 PM	**12:40 PM**	Daqin Wang, *Ou Tang*, Jiazhen Huo ***"On Rationing Policies in Inventory Models with Two Demand Classes and Lost Sales"***
12:45 PM	**02:00 PM**	Lunch
02:00 PM	**02:55 PM**	*Guangyuan Yang* **"Performance-Based Logistic Risk Management in Closed-Loop Supply Chains"**
03:00 PM	**03:55 PM**	*Yannick Deflem* and Inneke Van Nieuwenhuyse **"Optimal Pooling of Inventories With One-Way Substitution"**
03:55 PM	**04:25 PM**	Coffee Break
04:25 PM	**05:20 PM**	*Mario Guajardo* and Mikael Rönnqvist **"Inventory Management of Spare Parts in An Energy Company"**
05:25 PM	**06:05 PM**	*Geert-Jan van Houtum* **"Service Logistics: Developments in Practice and Research Challenges"**
07:00 PM	**10:00 PM**	Summer School Dinner

Wednesday - 24.08.2011

08:30 AM	**12:00 AM**	*Mercedes-Benz Factory Excursion*
12:00 AM	**13:00 PM**	*Lunch at Mercedes-Benz*
14:00 PM	**18:00 PM**	*Tour of Topkapi Palace and Basilica Cistern*

Thursday - 25.08.2011

09:30 AM	**10:25 AM**	*K. Hoen*, T. Tan, J. Fransoo, G. van Houtum **"Changing Transport Modes To Meet Carbon Emission Targets"**
10:30 AM	**11:25 AM**	*Laura Bettoni* and Simone Zanoni **"Lot Sizing and Energy Efficiency in Production/Inventory Systems"**
11:30 AM	**12:00 AM**	Coffee Break
12:00 PM	**12:40 PM**	*Oben Ceryan* **"Dynamic Pricing of Substitutable Products in the Presence of Capacity Flexibility "**
12:45 PM	**02:00 PM**	Lunch
02:00 PM	**02:55 PM**	*Laura Mazzoldi*, Ivan Ferretti and Simone Zanoni **"Multiproduct Economic Lot Scheduling Problem With Returns"**
03:00 PM	**03:55 PM**	*Mustafa Hekimoğlu* and Rommert Dekker **"Value of Slow Moving Items Obtained From Dismantled End Product"**
03:55 PM	**04:25 PM**	Coffee Break
04:25 PM	**05:20 PM**	*Danijel Kovačić* and Marija Bogataj **"Lead Times and Repeated Reverse Logistics in Extended MRP Theory"**
05:25 PM	**06:05 PM**	*Zsoly Matyusz* and Atilla Chikàn **"Company Competitiveness and Inventory Efficiency"**

Friday - 26.08.2011

09:30 AM	**10:25 AM**	*M. Güray Güler*, Taner Bilgiç and Refik Güllü **"Joint Inventory and Pricing Decisions with Reference Effects"**
10:30 AM	**11:25 AM**	Olof Stenius, Gönül Karaarslan, Johan Marklund and Ton de Kok **"Shipment Consolidation and Compound Poisson Demand"**
11:30 AM	**12:00 AM**	Coffee Break
12:00 PM	**12:40 PM**	*Murat Kaya* **"Behavioral and Experimental Research on the Newsvendor Model"**
12:45 PM	**01:45 PM**	Closing: *Atilla Chikàn*

10th ISIR Summer School

List of Discussants

Presentation By	Primary Discussant	Faculty Discussant
Laura Bettoni	Stephanie Vogelgesang	Zsolt Matyusz
Josephine Clemens	M. Güray Güler	Ou Tang
Yannick Deflem	Arkadi Seidscher	Onur Alper Kılıç
Ece Zeliha Demirci	Guangyuan Yang	Henk Zijm
Mario Guajardo	Willem van Jaarsveld	Baris Selcuk
M. Güray Güler	Sandra (A.C.C.) van Wijk	Oben Ceryan
Mustafa Hekimoğlu	Laura Mazzoldi	Refik Güllü
K.M.R. (Kristel) Hoen	Ece Zeliha Demirci	Refik Güllü
Willem van Jaarsveld	K.M.R. (Kristel) Hoen	Geert-Jan van Houtum
Danijel Kovačič	Josephine Clemens	Attila Chikán
Laura Mazzoldi	Danijel Kovačič	Refik Güllü
Arkadi Seidscher	Olle Stenius	Yacine Rekik
Olle Stenius	Yannick Deflem	Nesim Erkip
Maximiliano Udenio	Mustafa Hekimoğlu	Murat Kaya
Sandra (A.C.C.) van Wijk	Mario Guajardo	Stefan Minner
Stephanie Vogelgesang	Maximiliano Udenio	Gurdal Ertek
Guangyuan Yang	Laura Bettoni	Aybek Korugan

LOT SIZING AND ENERGY EFFICIENCY IN PRODUCTION/INVENTORY SYSTEMS

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In the last 100 years, energy consumption is severely increased, specially the consumption of non-renewable energy: this increase significantly the price of energy. So it's become very important for firms to decrease energy consumption in production processes in order to decrease energy cost. Moreover firms are looking for to reduce environmental impact of processes, to improve environment and its preservation.

Different studies have addressed the issue of increasing energy efficiency in manufacturing plants. Improve energy efficiency means to implement corrective actions that act on existing processes.

The existing bibliography shows different approaches to improve energy efficiency, two are the main approaches: technological and management, which propose new models and methodologies to reduce the energy consumption. To improve energy efficiency the main corrective actions of the technological approach are the replacement of the obsolete machines or motors and the use of inverter; while the management tools are based on the lot sizing, scheduling and production planning to decrease energy consumption. Our study focuses on the management tools.

The aim of this study is to propose a model so as to minimizes the total cost of a manufacturing system considering also the energy consumption. The system analyzed consists of two machines in series and two stocks, one of work in progress and one of finished products at the end of the system. The assumption of this assessment is variable production rate for both machines; backorder and stock out are not allowed so the demand must always be satisfied.

This work proposes a model to calculate the total cost of the system considering the contribution of energy, moreover the model allows evaluating what are the optimal production rates of the machines so as to minimize energy and total costs. The total cost is calculated considering the set-up cost of the machines, the inventory cost of the stocks and the cost of energy, which include the production cost, i.e. the cost of energy during production state, the start-up cost, i.e. the cost of the energy necessary to turn on the machine, or alternatively the idle cost, i.e. the cost of energy to hold on the machine in idle state, for both the machines considered in the system.

A numerical analysis was performed. The results show that the minimum total cost of the system depends on production rates of the machines and can be obtained running the machines at their lower production rates or at their higher production rates, depending of the idle power of the machine.

Once defined the idle power of the machines, this model allows to decide which are the optimal production rates which the machine have to run to minimize energy cost and total cost of the system.

ANALYSIS OF THE SUPPLY CHAIN COORDINATION POTENTIAL OF DIFFERENT CONTRACTS UNDER RANDOM PRODUCTION YIELD

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The various actors in a supply chain usually make their decisions based on individual profit maximization. Generally, such behavior leads to efficiency losses for the supply chain as a whole. By coordinating individual decisions, however, those efficiency losses can be avoided. In this context, appropriately designed contracts set incentives which induce the decision makers to deviate from their initial goal to maximize own profit towards supply chain optimal behavior. In cases where the supply chain suffers from unreliable production processes which result in random production yields, the complexity with respect to decision making and the determination of contract parameters amplifies. Only recently and to a rather small extent the topic of supply chain coordination under stochastic production yield has been dealt with in literature. Gurnani and Gerchak (2007) show how penalty contracts can coordinate a converging supply chain assuming deterministic end customer demand. Yan et al. (2010) extent this approach and prove that surplus subsidy contracts can enable coordination if there exists a secondary market for excess units at the end of the period. In contrast to that, Güler and Bilgic (2009) assume stochastic end customer demand and find that a buy back contract with revenue sharing and a penalty component is able to coordinate the supply chain. For a serial supply chain facing stochastic end customer demand, He and Zhang (2008) suggest various risk sharing contracts but without analyzing their coordination potential. A serial supply chain with one supplier and one buyer is considered where the buyer orders from the supplier who in return decides on a production quantity and delivers to the buyer. In this single period interaction, two scenarios regarding the handling of random production yields are analyzed. In the first case the compensation of potentially insufficient production output is not an option which possibly leads to a shortage and consequently to underdelivery. In the second case, however, missing quantities can be procured from an emergency source without uncertainty. If not stated differently through a contract, excess units are disposed off. Both scenarios will be further differentiated with regards to deterministic and stochastic end customer demand. For each of the four identified scenarios, the intention is to analyze the ability of different contract types to coordinate the supply chain.

Commencing with the simple wholesale price contract, the structures of the additional incentive schemes increase in complexity. Depending on the specific scenario, different contracts types are studied. One analyzed contract aims at sharing the risk of overproduction by making the buyer pay for excess units. Under another contract the supplier bears all risk and is additionally penalized for potentially missing units. A further contract determines that the buyer shares the risk of underproduction, i.e. the extra cost if an emergency source is available and has to be utilized. Besides those, the coordination potential of a combined buy back and revenue sharing contract is examined.

References

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Güler M.G., Bilgic T. (2009) On coordinating an assembly system under random yield and random demand. European Journal of Operational Research 196(1) 342-350.

OPTIMAL POOLING OF INVENTORIES WITH ONE-WAY SUBSTITUTION

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Successful inventory management deals with balancing the cost of inventory (typically reflected in the inventory holding cost) with the benefits of inventory (e.g. improvement in customer satisfaction, economics of scale in purchasing). One way of reducing the cost of inventory is by pooling the demands of multiple products on the same flexible item: provided that demands are not perfectly positively correlated, pooling multiple demands on the same item allows a reduction in the required amount of safety stock, and (hence) a reduction in inventory holding cost. Nevertheless, flexibility usually comes at a cost: this “flexibility cost” can boil down to a product cost premium (when the flexible item is inherently more expensive to manufacture or purchase) and/or an additional adjustment cost (when the item needs to undergo additional processing or transportation in order to make it “fit for use” when demand arises). This observation has spurred research on so-called substitution systems, in which a high-quality (and hence, more expensive) item fulfills its own demand and simultaneously acts as backup safety stock for the (cheaper) low-quality item (Khouja et al. 1996, Bassok et al. 1999, Liu and Lee 2007). Substitution flexibility can be obtained in a variety of ways, a.o. through the use of manufacturer-driven one-way substitution (Bassok et al. 1999, Rutten and Bertrand 1998), lateral transshipments (Robinson 1990, Herer et al. 2006) and tailored postponement (Tibben-Lembke and Bassok 2005).

Our research aims at investigating the optimal design of a 2-item inventory system with one-way substitution. We present two models --a newsvendor model for a single period setting and a discrete time Markov model for a multiperiod (R,s,S) setting with full backlogging-- that enable to derive the optimal inventory control parameters in view of minimizing the expected total cost per period (i.e. sum of inventory holding costs, purchasing costs, backorder costs and adjustment costs). The model allows for correlated demand; replenishment lead times are assumed to be negligible.

Numerical experiments for the multiperiod setting show that the one-way substitution strategy outperforms both the “no pooling” strategy (in which only product-specific stock is held, and demand can never be rerouted to stock of a different item) and the “full pooling” strategy (implying that demand for a particular product type is always rerouted to the stock of the flexible product, and no product-specific stock is held). Furthermore, we can observe that a decrease in demand correlation results in rerouting more demand to the flexible product; because of the riskpooling effect, this reduces the optimal expected total cost.

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OPTIMAL INCENTIVE DESIGN FOR PUBLIC-INTEREST GOODS

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The price of a public-interest good significantly affects the order quantities of populations when the main concern for these decision processes is the expected profit. However, for this category of goods taking decisions only based on the expected profit leads to disparity between populations. In order to ensure equivalence between populations, a central planner can control prices charged to populations by giving incentives to them. In this context, we analyze the problem of determining optimal incentive design in an environment, where the central planner has limited budget. The goal of the central planner is to maximize total utilities obtained from populations. Main feature of the study is formulating the problem as a bi-level program; specifically it allows us to consider the central planner's objective as well as the objectives of parties involved in the manufacturing and retailing of the good. Analytical results for structural properties, as well as numerical results are obtained. Note that the environment under consideration has practical importance in various settings and typical examples are as follows: vaccine supply chain, carbon dioxide emission trading, urban planning etc.

INVENTORY MANAGEMENT OF SPARE PARTS IN AN ENERGY COMPANY

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This work is motivated by a real-world problem in an international energy company. Headquartered in Norway, the company is one of the largest suppliers of oil and gas. Spare parts are needed as part of the maintenance at the installations of the company. Our research is aimed at supporting the inventory management of spare parts of the company. We study the inventory levels and the structure of the network of inventories.

The company's activities include extraction of crude oil, processing and gas treatment. Several types of equipment are used in these activities. The company holds inventory of spare parts to repair or replace its equipments, in order to assure operating conditions. The company has operational responsibility for 7 warehouses serving offshore installations. Within this structure of warehouses, there are 24 plants. Each plant holds inventory of spare parts. They manage their inventory separately. When maintenance at a given installation takes place, the required spare parts are provided from the corresponding plant. If not stored, the spare parts are procured directly from a service parts supplier. There are about 245,000 types of items in the inventories. Some of these are highly critical to assure safety and production. At the same time, the store of spare parts means an important binding cost for the company, in the order of 600,000 million euro. The frequency of the requirement for a given spare part and the amount in which is needed are, in general, highly uncertain and, in some cases, intermittent. The amount of each spare part required for a given project in a given plant is determined in two stages. Firstly, the service parts supplier proposes an amount of parts. Secondly, the inventory manager evaluates and decides the final amount. In practice, the expert judgment of the inventory managers plays currently a key role in the decision making rather than a structured methodology.

Our research focuses on two major aspects. The first is to develop a quantitative evaluation methodology which suggests inventory levels. It appears that current levels are over-estimated, thus significant capital binding and other costs are incurred. We support the company on deciding how many spare parts are needed in inventory, such that risk of production's breakdowns are as equal or better as in the current situation while at the same time reducing the cost of the inventory.

Secondly, we analyze how risk pooling between the inventory plants can be implemented. Under the current network, each of the plants analyzes its necessities of spare parts per separate. There is a potential of important savings on inventory costs for the company if it manages the inventories under an integrative approach. Our research contributes with an important case study in the energy industry which, despite its worldwide importance, it has not been a main protagonist in the literature of spare part inventories so far. Based on our experience working closely to the inventory managers of the company, we believe there are important opportunities to improve the current practices in the industry.

JOINT INVENTORY AND PRICING DECISIONS WITH REFERENCE EFFECTS

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We consider a joint replenishment and pricing problem of a monopolistic firm. The firm has to decide both the price and the inventory replenishment quantities simultaneously in order to maximize profit. The demand is contingent on price. However price is not the only factor that affects the demand. As customers buy a particular product frequently, they develop their own price expectations, which is called the reference price. These reference prices become the benchmark against which current prices are compared. Reference price is observable to the firm at the beginning of the period before giving pricing and replenishment decisions. If the current price is greater or less than the reference price, then it is perceived as **loss** or **surcharge**, respectively. The customers have different attitudes to these perceptions, such as loss-aversion, loss-neutrality or loss-seeking. Therefore the random demand is not only contingent on the product's current price but also on the price history which is captured by its reference price. Hence the inventory and pricing policy is affected by the reference price. This dependence can be through the absolute difference, or the percent (relative) difference between the price and the reference price. Although a firm can increase its profit in a period with a price discount, future reference price of customers decreases with this discount which results in a loss in future periods. Likewise, increasing the price has the reverse effect for the current and future profits. Therefore the firm faces a trade-off between the current and future benefits.

This study aims to identify an optimal joint inventory and pricing policy for a firm that faces a random demand which depends on the price and the reference price. Our goal is ***(i)*** to show that an order-up-to policy is optimal under certain assumptions, ***(ii)*** to find the effects of cost parameters and reference effect mechanism on the expected profit and ***(iii)*** to investigate the value of dynamic programming vs myopic policy and the cost of ignoring the reference effect.

VALUE OF SLOW MOVING ITEMS OBTAINED FROM DISMANTLED END PRODUCT

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For spare parts of products which are in the last stage of their life cycle, using alternative supply methods is important. Dismantling an old product and using its spare parts for the ones that are in use is one of the possible ways of getting the required item for maintenance companies. Especially getting slow moving items through dismantling could be beneficial for service providers since these items are expensive and can create significant inventory holding costs. However, these spare parts are always subject to sudden obsolescence risk due to sudden technological or environmental changes in customer base. Furthermore, alternative supply methods have negative effects on the profitability of the supplier. Suppliers may stop producing the spare part if they cannot foresee any significant profit in future. Supply cut of required spare parts may force the company to make significant investments and retire existing capital before its lifetime expires. Therefore decision maker has to consider both obsolescence and supplier risks in pricing of spare parts coming from dismantling process. In this study, a Markov decision process considering both demand obsolescence and supply cut risk is evaluated. Product life time and interarrival time of spare part demand is assumed to be exponentially distributed.

We show the convergence of total expected reward functions of Markov decision process. The formulations of reward functions for each state are given as a system of linear equations. Difference of expected rewards for two consecutive states gives the value of getting an additional item for given inventory level. This value is calculated for general (S,s) system in which S=N. Furthermore, we show the effect of considering obsolescence and supply cut in pricing of a dismantled spare part. We show that getting a spare part from dismantling process decreases as inventory level increases for a given base stock level. Besides, when the obsolescence and supply cut risks are ignored, the value of getting a spare part from dismantling is significantly larger than the full model. We conclude that for slow moving inventories, such as spare parts of high-tech manufacturing equipments or aircrafts, both demand obsolescence and supply cut should be considered together. Analytical insights are tested with real data from maintenance service provider in aviation sector.

CHANGING TRANSPORT MODES TO MEET CARBON EMISSION TARGETS

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In this research we consider a company that is committed to reducing carbon emissions within the supply chain. In practice and theory, most emission reduction efforts so far have been targeted towards reducing emissions from production and (indirect) emissions from electricity consumption: Scope 1 and 2 of the Greenhouse Gas Protocol. We consider an important source of Scope 3 emissions: emissions from outsourced transport. Around 20-25 % of all greenhouse gas emissions in Europe in 2006 were caused by transport (including private transport). The emissions from transport in absolute numbers are still increasing due to increased demand for transport (shipping more products and over longer distances). Several measures are available to reduce emissions from transport, which range from making structural changes to the supply chain to changing operational decisions. The company we consider has outsourced all transport activities to a Third-Party Logistics provider. We focus on an operational easy-to-implement measure that leads to carbon emission reductions that is under the control of the shipper: shifting transport to 'greener' transport modes, most notably intermodal rail and water transport.

An issue related to generating insights in carbon emissions from outsourced transport is the measurement of the emissions. Fuel bills can directly be translated into carbon emissions per ton kilometer (1 ton of cargo shipped over 1 kilometer) but in general logistics service providers are understandably unwilling to provide them. We therefore use in our model a method which is grounded in European studies to estimate the emissions from transport. The method is developed by NTM and has been extended to an online calculation tool.

We focus on a multi-item model in which an emission constraint is set for all products together for a particular time-period, which may correspond to an emission reduction declaration by the company CEO. Demand is considered to be deterministic and dependent on the price of the product and the emissions from transport. For each product and each transport mode we determine the sales price that maximizes profit. We develop a model that generates insights for a product which mode is preferred from a pure cost perspective and at what cost a certain emission reduction can be achieved. We are able to determine the most cost-efficient transport mode allocation for a given emission target.

In a numerical study based on real-life company data we identify the emission abatement curve, in which emission reduction versus cost increase is plotted. We identify the maximum possible emission reduction by changing transport modes. Lastly, we elaborate on factors that determine whether relevant emission reductions can be obtained at a reasonable cost increase.

SPARE PART INVENTORY CONTROL FOR A COMPONENT REPAIR SHOP

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During aircraft maintenance, unserviceable components are removed from the aircraft and sent to shops for repair. Only after an unserviceable component is inspected at the repair shop, it becomes clear which specific spare parts are needed (and in what quantity) to repair the component. Because airlines require short repair times of these components and since spare parts may have a significant leadtime, it is essential to keep a stock of spare parts at the repair shop. On the other hand, such a stock can be costly, because of the high price of some spare parts and since a broad assortment is needed to attain a good performance. Moreover, since some parts are relatively cheap, there is the issue of determining appropriate order batches. In a recent project we have studied the inventory control of spare parts at such a repair shop. The problem is complex, because the inventory decisions are made on a spare part level, while constraints should reflect the requirements on the availability of specific component types. Because spare parts can often be used in the repair of multiple component types, the inventory policy of the spare parts must be jointly optimized. In that sense, the problem is related to the problems encountered in the study of Assemble To Order (ATO) systems; for an overview see Song and Zipkin (2003). We model the problem in a similar fashion as the ATO problems in literature. We incorporate batching by presuming an (s; S) (min/max) policy for each part. In practical problems over 10000 spare parts and over 1000 components need to be considered. Because of the combinatorial nature of the problem, problems of such size pose a significant computational challenge. Our contribution consists of proposing a method that is able to cope with problems of such sizes. Our approach rests on linearizing the constraints, which allows us to model the problem as an IP. Depending on the precise setting, this linear formulation may be exact, or it may approximate the true problem. Our solution method is based on column generation on the LP relaxation of this IP. The pricing problem can be solved for each part individually. This problem has to be solved a large number of times, so an efficient algorithm is in order. It turns out that existing algorithms (Zheng and Federgruen 1991) are not applicable. We therefore propose a novel algorithm to solve the pricing problem

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LEAD TIMES AND REPEATED REVERSE LOGISTICS IN EXTENDED MRP THEORY

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MRP Theory, which has been well developed over the past two decades by Grubbström et al., has been mostly used in modeling production processes. Global supply chains also contain distribution and consumption processes and since the importance of reverse logistics is increasing, this theory was recently extended to incorporate all kinds of activities. This paper presents such an extended model in a generalized form, using input-output analysis for description of the structures and Laplace transforms for proper inclusion of lead times. Production lead times appear inside production and recycling sub-processes. Because of geographical dislocation, individual transportation lead times appear inside and between any of the four sub-system(s). Special focus is given to recycling sub-process. Transportation costs of recovered items back to production and of waste items to landfills influence the overall Net Present Value. This emphasizes the importance of recycling facility locations in combination with environmental taxation.

Keywords: MRP Theory, multistage reverse logistics, input-output analysis, Net Present Value (NPV)

MULTIPRODUCT ECONOMIC LOT SCHEDULING PROBLEM WITH RETURNS

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In this work we consider a hybrid manufacturing/remanufacturing system with an additional sorting line. In particular, we consider a company that collects returned products from service assistance, and evaluates the possibility of remanufacturing them, distinguishing remanufacturable and not remanufacturable products. Remanufacturable products are remanufactured as good as new ones, while the others are sent to the disposal system and newly manufactured ones are produced within the system in order to satisfy the demand.

We can model the system as a variation of the ELSP model. As the ELSP problem is NP-hard (Hsu 1983), the focus of most research efforts has been to generate near-optimal repetitive schedule(s). In order to do this, several heuristic solutions have been proposed using any one of the common cycle (CC), basic period (BP), or time-varying lot size (TVLS) policies.

The CC policy always produces a feasible schedule and is the simplest to implement, however in most cases the solution is far from the optimal one. Adopting a BP policy usually guarantees a better solution (Raza and Akgunduz 2008) allowing different cycle times for different products, however the cycle time length must be an integer multiple of the basic period. However, the BP approach unfortunately, when the capacity utilization of the system resources is quite high, generates several infeasible schedules. Finally the TVLS policy introduced by Dobson (Dobson 1987) is more flexible than the others,allowing for different lot sizes for the different products in a cycle. He also showed that TVLS always produces feasible schedules, as well as giving better quality solutions.

The problem is modeled as a multi-level inventory system, with three stocks (Used products (returns) inventory, Remanufacturables inventory, and Serviceables inventory), each characterized by an inventory holding cost, and three limited capacity resources: a sorting line, which enables the company to discriminate remanufacturable returns from those which are not; a remanufacturing line to carry out operations on remanufacturable returns; a manufacturing line to produce new products in order to satisfy the demand, which is assumed to be constant over time and depletes the finished products inventory (the Serviceables inventory) continuously by a constant rate over time. Each resource is characterized by a setup time and a setup cost, as well as a constant production rate, while each stock implies an inventory holding cost. The objective of the paper is to develop a model for the considered production system under the ELSP model formulation, which goal is to minimize the sum of setup and inventory holding costs. The problem has been inspired by the works of Tang and Teunter (2006), Teunter et al. (2008, 2009).

In order to provide optimal or near-optimal solutions under the BP assumption for the considered production system model formulation, an heuristics has been developed and some numerical studies has been carried out to analyze its performance.

A SEMI-MARKOV DECISION PROBLEM FOR PROACTIVE AND REACTIVE TRANSSHIPMENTS BETWEEN MULTIPLE WAREHOUSES

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Lateral transshipments are an effective strategy to pool inventories. We present an exact Semi-Markov decision problem formulation for proactive and reactive transshipments in a multi-location continuous review distribution inventory system with Poisson demand and exponential replenishment lead times. In a numerical study, we investigate the benefits of proactive over different reactive transshipment rules depending on the design of the distribution network, cost parameters, and demand and supply parameters. We find that the benefits of proactive transshipments are the largest for networks with intermediate opportunities of demand pooling and that the difference between reactive transshipment rules is negligible.

Keywords: Lateral Transshipments, Inventory Control, Multiple Locations, Markov Decision Problem

EXACT ANALYSIS OF DIVERGENT SYSTEMS WITH TIME-BASED SHIPMENT CONSOLIDATION AND COMPOUND POISSON DEMAND

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Sustainable and efficient management of a distribution system requires coordination between transportation planning and inventory control. In this context, we consider a divergent two-echelon system with one warehouse and multiple non-identical retailers with a time-based shipment consolidation policy where retailer orders are consolidated at the warehouse and shipped to groups of retailers periodically. Customer demand is compound Poisson distributed and unsatisfied demand at each stockpoint is backordered and at the warehouse they are shipped with the next available shipment according to a first come first served manner. The system is centralized and inventory levels are reviewed continuously, which means that the warehouse has access to point of sale data and all inventory information at the retailers. All retailers apply order-up-to S replenishment policies, whereas the warehouse, which replenishes from an outside supplier/manufacturer with a constant replenishment lead time, uses a traditional (R,Q) policy. We derive exact expressions of the long-run average holding and backorder costs, average inventory levels and service levels. Moreover, we derive exact probability distributions of the inventory levels at the retailers, which allow us also to calculate the fill rates for the retailers. The analysis of the inventory levels at the retailers is done by determining the distribution of the warehouse backorders designated to each retailer. Based on the analytical properties of the objective function, we construct an exact optimization procedure for determining the optimal reorder levels at each stockpoint both for single item and multi-item cases. This optimization can be performed both for cases with shortage costs and fill rate constraints. We also optimize the shipment intervals based on the assumption that there is a fixed shipment cost associated with each scheduled shipment leaving to a specific retailer group. As a result of the analysis of the backorders at the warehouse a "backorder imbalance" is quantified, which prove that different retailers experience different service from the central warehouse dependent on the order sizes of the individual customer orders. More specifically we are able to prove that in the cases when the inventory position at the central warehouse is positive a retailer with stochastically larger order sizes will experience a longer average waiting time per demanded unit than a retailer with smaller order sizes. In the cases when the inventory position is negative, the relationship between order sizes and the average waiting time is opposite.

SALES FORECASTING DURING THE CREDIT CRISIS

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The world economy experienced a sudden, severe and synchronized collapse in late 2008. Managers faced, in the final quarter of 2008, the challenge of making instrumental decisions while in the midst of an unprecedented crisis. Demand forecasting is an instrumental part of any supply chain. Regardless of the industry, the kind of process or the physical location of a plant, supply decisions depend on demand forecasts. Any process generating a forecast makes explicit or implicit assumptions about the underlying stochastic demand process; no such process is prepared to respond to severe shocks in the system. The recent financial crisis introduced one of those shocks: an inventory shock. Industries involved in physical goods, whether manufacturing, distribution or retail, responded to the crisis in a way that can be summarized by the motto "cash is king". The world's financial instability meant that liquidity was a prized asset, a way of guaranteeing companies' survival. When taken individually, these de-stocking decisions do not have a measurable effect on the economy; but when the de-stocking is synchronized across and within industries, an inventory shock is introduced. We hypothesize that in fact the inventory shock on September 2008, was one of the main factors that drove the demand pattern during the subsequent two years. In this paper we analyze the strong dip in the manufacturing industry seen at the end of 2008 and provide evidence from various sources that it was caused by cumulative de-stocking triggered by the very public onset of the crisis around the time when Lehman brothers declared its bankruptcy. We model the course of the demand during this period as a consequence of replenishment decisions taken along a multi-level supply chain and validate the model using data from a number of business units and market segments of Royal DSM NV, a dutch life sciences company. We use system dynamics as a modeling environment and base our methodology in Sterman's beer game and supply chain models (1989, 2000). The model does not do any econometrical fitting, nor does it use any general market data for the customer segments that the company directly ships to. Instead, it uses the structure of the supply chain and the inherent replenishment process to model the dynamic response to a pair of exogenous inputs: the end market demand evolution and the synchronized de-stocking shock. We show that (1) we can explain the dynamics of demand realizations using such an inventory replenishment model and that (2) such an approach can be used to forecast aggregate demand in the medium to long term. Forecasts were produced in mid 2009 for four different segments. These were incorporated in the respective S&OP processes and proved to be more accurate than traditional forecasts and a key strategic asset in some of these business units' response to the crisis. Figure 1 shows one of such forecasts, compared to the actual realizations observed in the segment.

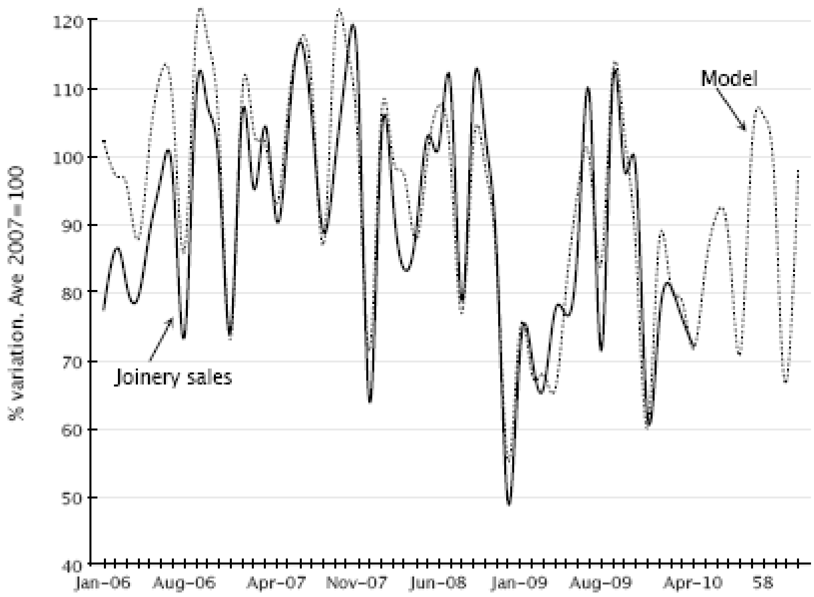

Figure 1 – Seasoned model output vs. unadjusted joinery sales.

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LATERAL TRANSSHIPMENTS IN SPARE PARTS INVENTORY MODELS

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We consider an inventory system with multiple stock points. When a demand occurs at a stock point and there is a part on stock, the demand can be immediately satised. Otherwise, one may apply a lateral transshipment, in which case a part is shipped from a nearby stock point, if it has a part available. The demand is lost otherwise. Both options have a cost, and the optimal choice may depend on the stock levels of all stock points in the system. For inventory problems with lateral transshipments, currently only limited insights are available on optimal policy structures. It is known that a lot of costs can be saved via lateral transshipments; see in particular Kranenburg [2006], who showed a cost reduction of 50% for a spare parts inventory control problem at ASML, an original equipment manufacturer in the semiconductor industry, compared to the situation without lateral transshipments. But, there is a lack of insights into when exactly costs can be saved via lateral transshipments. This depends on the parameters settings, such as the costs for a lateral transshipment.

In previous research, we solved the two location problem, for which we completely characterized the structure of the optimal policy. We derived conditions under which simple, easy to implement, policies are always optimal. Furthermore, we identifed the parameter settings under which one can gain most from lateral transshipments. Currently, we are focusing on multi-location models, with more than two stock points. For a special case, where only one stock point issues lateral transshipments, we characterized the optimal policy structures. However, our current techniques do not straightforwardly generalize to the general multi-location model. Hence, we have to restrict the possibilities for stock transfers in our model. Firstly, we only allow lateral transshipments when a location is stocked-out, although this can be suboptimal in the two location model. Secondly, we probably have to limit or restrict the transshipments between the stock points.

For this model, we want to prove that a so-called hold back pooling strategy is optimal. In this case a stock point can hold it last part(s) back from a lateral transshipment, which is determined by its hold back level. Then, we want to gain insights in the optimal settings of these hold back levels. That is, we want to optimize the lateral transshipment policy within the class of hold back policies. Moreover, from an implementation point of view, such a simple, parameterized policy may be much more attractive than an overall optimal policy. Furthermore, we investigate the gap between the optimal hold back policy and the overall optimal policy.

DEMAND AND YIELD RISKS IN PRODUCTION SYSTEMS – TESTING THE QUALITY OF LINEAR ORDER RULES VIA SIMULATION

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Fundamental assumptions of basic MRP-type inventory control systems like deterministic demand and production yield are not given in an environment that is affected by uncertainty. Therefore, an explicit consideration of demand and yield risks is essential. For this purpose the relevant literature suggests the use of a safety stock and a yield inflation factor (YIF) in an MRP-type inventory control system to cope with the influence of demand and yield risks (see Inderfurth (2009); Nahmias (2009); Vollmann et al. (2004)). For the special case of a single item single-stage inventory control system under periodic review several authors (see Gerchak et al. (1988); Henig and Gerchak (1990)) have analyzed that the optimal policy for cost minimization results in a critical stock (CS) rule in combination with a non-linear order release function. However, from practical viewpoint it is really cumbersome to incorporate this complex order rule in existent inventory control systems. From the results in Bollapragada and Morton (1999) it is well known that a linear-control rule as approximation to the non-linear order release function performs quite well. The main idea is to determine appropriate safety stocks (as part of CS) as parameter for the linear control rule, that enables a quite good approximation to the non-linear order release function. Using a fixed YIF (that is the reciprocal of the mean yield rate) as in Bollapragada and Morton and a time-dependent CS Inderfurth and Gotzel (2004) and Inderfurth (2009) extend the parameter determination approach in Bollapragada and Morton to cases with arbitrary lead times considering stochastically proportional yield. As in the case of non-zero lead time the parameter determination approach results in safety stocks that vary from period to period, Inderfurth and Vogelgesang (2011) present different approaches of how these dynamic safety stocks can be transformed into static ones in order to facilitate applicability of safety stock usage. Just recently Huh and Nagarajan (2010) revisited the linear control rule problem under zero lead time in Bollapragada and Morton and developed an approach for calculating optimal values of CS for a given YIF for the case of stochastically proportional yield. They proof that for any given YIF the average costs are convex in CS and exploit this property in deriving a calculation procedure in which the static CS is determined via simulation. For testing the quality of the static safety stocks that can be determined with the Inderfurth/Vogelgesang-approach we will compare the results of a comprehensive simulation study with the results of the Huh/Nagarajan-method under zero lead time. Furthermore, the results from the application of dynamic safety stocks in a simulation study can be used as a benchmark for the static safety stocks in the non-zero lead time case. Our aim is to extend the Huh/Nagarajan method so that we can calculate the optimal CS for a given YIF also in cases with arbitrary lead times as benchmark to our method, which is easier to handle in practical applications.

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PERFORMANCE-BASED LOGISTIC RISK MANAGEMENT IN CLOSED-LOOP SUPPLY CHAINS

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We developed a decision support system to mitigate risks of extreme repair costs in closed-loop supply chains with performance-based contracts.

Differing from the traditional transaction-based logistics where repair costs are paid by each individual customer for each repair, performance-based logistics transfer these costs from customers to the capital goods MRO (Maintenance Repair & Overhaul) service provider, by charging customers fixed fees or flat fees per operating hour for a guaranteed availability of serviceable critical components (to exchange failed components). Therefore, the service provider has to manage uncertainties in repair costs, especially the risk of extreme repair costs.

In a closed-loop supply chain of post-production capital goods MRO, one has to procure a serviceable component from the secondary market in order to prevent an extremely expensive repair, given the guaranteed availability. Instead of procuring the components reactively when extreme repair costs are about to incur, we propose a proactive procurement strategy because of highly asymmetric information and great uncertainties of availability and prices in the secondary market. This proactive strategy enables the MRO service provider to search for components over more brokers and to negotiate for lower prices, such that extremely expensive repairs can be avoided with limited procurement costs.

We first apply the Extreme Value Theorem to evaluate the risk of the extreme repair cost for each critical component. We then analyze the trade off between the risk of the extreme repair cost and proactive procurement costs, taking into account the expected extra holding costs due to the procurement. Furthermore, based on the non-parametric approach of the Extreme Value Theorem and the statistical distribution of the extreme repair costs (over a certain threshold), we obtain the expected number of extremely expensive repairs in a certain period. As a result, we can provide purchasing limits (both prices and quantities) for the proactive procurement strategy.

A case study in an independent performance-based aircraft MRO service provider shows our results are very promising, such that the provider has implemented our decision support system in its procurement and repair operations. The tool helps the provider make correct and fast procurement decisions when opportunities appear in the market. It also helps the provider decide whether to repair, to not repair but store for future use, or to not repair and scrap. Furthermore, due to the highly asymmetric information in the market, our proactive strategy and its purchasing limits give great advantages to the provider in procurement negotiations. Last but not least, our results have also been used for dismantling aircraft projects.