Book of Abstracts

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TABLE OF CONTENTS

PLENARY PAPERS

ECONOMICS OF INVENTORIES

INVENTORY MANAGEMENT

MATHEMATICAL MODELS OF INVENTORIES

FORECASTING FOR INVENTORIES

IMPLEMENTION OF INVENTORY MANAGEMENT THEORIES AND MODELS IN ORGANIZATIONS

INVENTORY AND THE ENVIRONMENT

RISK MANAGEMENT IN SUPPLY CHAIN INVENTORY SYSTEMS

SERVICE LOGISTICS

IN ABSENTIA

Remark: *Presenting author is the first author or whose name is marked with "*"*

PLENARY PAPERS

Challenges posed by a changing world

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In recent decades, the world has been confronted with dramatic societal changes that in turn have challenged many companies, logistic service providers and local and national governments to fundamentally rethink logistic infrastructures and to design adequate planning and control strategies. These changes include the ongoing trend towards mass customization, the shift in focus from products to services, the ageing population in western countries, and in particular environmental concerns that demand for more sustainable products and processes. In addition, political instability and the consequences of climate change may require new and innovative approaches in areas such as disaster and humanitarian logistics. At the same time, new technological developments provide an important asset that in principle should enable stakeholders to respond to these challenges, although more is needed. In this talk we discuss some of these issues and their consequences for the field of logistics and inventory management.

Inventories, monetary policy, and the market for new automobiles

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This paper investigates the effects of monetary policy on the market for new automobiles. A representative automobile firm is modeled 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. Our market-equilibrium model is estimated using quarterly micro-level data on new cars and light trucks. Monetary policy of course changes interest rates. 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.

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

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The 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. The "ideal" inventory is *S*. But because of the set-up cost one needs some distance to this ideal inventory before it is worth to order and return to *S* again. Interestingly, while the optimality of (*s*,*S*)-policies seems to be straightforward, the proof of the optimality is not at all trivial (e.g. Arrow, et al. [1]).

This combination of simplicity and complexity started a whole range of investigations into the structure of optimal policies for related inventory problems. For instance the case in which the production capacity is constrained, implying an upper bound *R* on the order quantity. In case of a positive set-up cost, one would expect the optimal policy to have the following structure: do not order if the inventory $I(t) \geq s$ and order the minimum of *R* and $S\text{-}I(t)$ if $I(t) < s$. However, this is not true. The general policy does not have a simple structure (e.g. Shaoxiang & Lambrecht [3]).

Another way to include a capacity constraint is to constrain the *production rate*, rather than the *production amount per review period*. We follow this idea here. 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. It will be proved that the average optimal policy is 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. We also provide a dynamic programming based numerical method that exploits the skip-free-to-the-right character of the system (Wijngaard & Stidham [4]).

The model studied here is a mix of classical inventory theory and queueing control, since the production rate in our inventory control problem can be interpreted as the service rate in a queueing control problem. Most relevant queueing control work is that on D-policies: policies that switch the server on as soon as the *workload* reaches a certain level (e.g. Feinberg and Kella [2]). An important difference is that the cost function in queueing control is non-decreasing, while this is not so for inventory control with backlogging.

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The effects of integrating human judgement into forecasting and stock control decisions

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A number of research projects have demonstrated that the efficiency of stock control systems does not relate directly to demand forecasting performance, as measured by standard forecasting accuracy measures. When a forecasting method is used as an input to a stock control system it should therefore always be evaluated with respect to its implications for stock control (through accuracy implications metrics), in addition to its performance on these accuracy measures. In this work we address the issue of judgementally adjusting statistical forecasts for both 'fast' and 'intermittent' demand items and the implications of such interventions both in terms of forecast accuracy and stock control, the latter being measured through inventory volumes and service levels achieved. We do so using a large empirical dataset from the pharmaceutical industry. The study allows insights to be gained into the combined forecasting and inventory performance of judgemental estimates. The practice of judgementally adjusting directly replenishment quantities is also discussed and preliminary results into this phenomenon are offered for the first time in the academic literature.

Keywords: Inventory forecasting; Human judgement; Periodic stock control

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A multi-echelon inventory control model for implementation in practice: The case of a global spare parts provider

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We present a simple model for optimizing reorder points in a multi-echelon distribution system with one warehouse and a number of non-identical retailers, which is flexible enough to be implemented in practice. The motivation for this work stems from close cooperation with a software provider of supply chain systems and one of their customers, a global spare parts provider. Important requirements posed on the model are that it should: (i) jointly optimize the reorder points in the system to meet target service levels for the end customers while minimizing the inventory costs, (ii) be applicable to realistic demand distributions, particularly where each customer order varies considerably in size, (iii) be able to handle direct customer demand at the central warehouse, (iv) be computationally feasible to use in large systems in practice, and (v) be conceptually simple enough to be understood by the end users.

The model may be described as a synthesis and extension of earlier work by Andersson et. al (1998), Andersson & Marklund (2000) and Berling & Marklund (2006). The model heuristically coordinates the inventory system in a decentralized manner, using an induced backorder cost at the central warehouse. This induced backorder cost captures the impact that the reorder point decision at the warehouse has on the retailers' costs, and decomposes the multi-echelon system into a series of single-echelon models. This decomposition framework makes it possible to obtain a very flexible model that is able to meet the challenging requirements listed above.

A numerical study illustrates that the new model performs well in comparison to existing methods in the literature. Moreover, a simulation study based on real data show that the new model offers significant improvements to the case company. In general the new model obtained realized service levels much closer to target while reducing total inventory by 35% on average. The software company is currently investigating how to implement the methodology into their system.

Keywords: Multi-echelon, Coordinated, Decentralized

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Measuring supply chain cost

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A critical issue for a company to gain a competitive position is to improve its supply chain performance. A study has investigated with interviews how 30 Swedish companies in ten different sectors define an excellent supply chain and work with Supply Chain Management, performance measurements and Supply Chain Costs.

Organizations focus on reducing costs in the supply chain to increase net income. It shows that the costs of the supply chain are measured in many different ways and with different accuracy. Based on the interviews a cost model is suggested to measure and perform a product and customer cost analysis covering all or at least most activities performed in the supply chain. Cost accounting can today, with help from computers and information technologies, be made quickly and accurate. A case study describes and shows the difference in measuring supply chain costs based on predetermined standard costs with percentage mark ups compared to measure it based on actual costs.

Keywords: Supply chain management, Supply chain performance, Supply chain costs, Management accounting, Cost analysis

ECONOMICS OF INVENTORIES

Optimal pricing and production planning decisions in reusable container systems

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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. Our approach utilizes constrained non-linear optimization techniques. The study is completed with the investigation of the model analytically and computationally. Our analytical and computational results show us 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.

Keywords: Closed-loop supply chains, Reverse logistics, Reusable containers, Deposit – refund systems

Inventories and national competitiveness

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Competitiveness of nations has become one of the central issues in economic analysis and policy in the recent decade. There are several internationally acknowledged systems of ranking nations on the basis of their competitiveness, using a number of factors based on mainly various survey technologies (the best known indeces are those of the World Economic Forum, the IMD and the World Bank).

In this paper we look for connections between aggregate inventory investment and national competitiveness in a set of OECD countries, where appropriate data are available. We examine this connection clustering countries by relevant factors of competitiveness and see if there are differences among inventory behaviour of countries in the different clusters. We examine changes of these relationships by different subperiods between 1987 and 2008, with special attention to the role of business cycles.

The effect of inventory investment on ecological footprint

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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. We show a new calculation method to determine the effect of capital accumulation on ecological footprint. The proposed method is demonstrated on the Hungarian dynamic input-output model.

Keywords: Leontief model, Ecological footprint, Environmental management, Allocation method

The evaluation of cannibalization and components commonality on inventory total cost Predictive model for intermittent demand on aircraft maintenance

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During maintenance actions, eventually maintenance providers will be confronted with the situation of spare-parts shortages. Sometimes, these shortages are highly problematic as they may compromise the entire process, especially in the aviation industry where it is intended that airplanes remain grounded for the shortest possible time. The purpose of this paper is to establish a straightforward approach to the maintenance procedure called cannibalization and to its benefits, and to compare these with those of other maintenance procedures; this will allow the maintenance provider to make an informed decision on which one is the most adequate in a specific repair process.

By definition, cannibalization is a procedure that consists in the interchange of identical parts between different assemblies (also referred as components) in order to fight spare parts shortages, either caused by lack of stock, excessively high lead-time/cost or obsolescence. In spite of being theoretically a simple procedure, it has some drawbacks that prevent cannibalization to be a peaceful concept. Due to these drawbacks, cannibalization is a maintenance procedure avoided by the greatest majority of maintenance providers, with the exception of the military field where it is enforced due to readiness and operational demands.

Instead of cannibalizing, usually maintenance providers rely on the manufacturer or the second-hand market to supply the part they require; sometimes, due to obsolescence, they decide to modify the component in order to upgrade it or even to manufacture the part themselves.

When the proposed model is put into action (which is threefold as it includes the three most important variables related to repair procedures – cost, lead-time and obsolescence), the output is a clear comparison between all the available maintenance procedures. Then, it is the maintenance provider's responsibility to choose the one which is the most suitable (either in terms of profits or obligations towards the customer). Moreover, a commonality study is also performed in this paper. Associated with cannibalization, it is intended to infer about the importance of these two parameters on the total inventory costs.

Keywords: Aircraft maintenance cost; Cannibalization; Commonality; Lot-sizing methods; Inventory costs

A model of capacity adjustment: Investment vs. inventories

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Motivation: We study the interaction between fixed investment and inventories in an environment where firms have to learn about the state of demand. Our study is motivated by empirical evidence from the U.S. manufacturing sector that indicates investment in inventories leads investment in fixed capital by several quarters.

We study an industry 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 becomes even more interesting when the firm has to learn whether a given change in demand is permanent or transitory. The intuition is as follows. The firm can 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 is subject to adjustment costs the firm would adjust the latter only if it has a strong belief that the shock is permanent. If the firm on the other hand believes that the shock is transitory it will adjust inventories.

To analyze this problem we build a model where finished goods inventories arise due to stock-out considerations (as in Bils and Kahn (2000)) and investment in capital is subject to both convex and non-convex adjustment costs, The firm learns about the nature of the shock affecting demand through Bayesian learning.

Results: We first analyze the rational expectations (no learning) benchmark and find that there is considerable interaction between investment in capital, inventories and employment.

In this environment we find that investment in capital and inventories are positively correlated as in the data but this crucially depends on the level of capital. For a low level of capital the correlation is higher than for a high level of capital (because due to the fixed cost component investment is zero in this region). We also find that employment is positively correlated with fixed investment but less so with inventory investment. We currently explore the learning case.

Keywords: Inventories, Fixed investment, Capital adjustment costs, Capacity adjustment, Production

Explaining the shifts in inventory behavior in the Finnish economy and different industries during the period 1980-2009

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In our paper we will first econometrically analyze the Finnish Inventory to Sales Ratios within different industries during the period of 1980–2009 using annual (and perhaps also quarterly) inventory data. Our goal is to look at the time trend of Inventory to Sales Ratio and to reveal significant breaks in the time trend at both the aggregate and industrial level. After recognizing the dates of significant breaks in trends we will try to find potential explainers for these phenomena. During the period analyzed the Finnish economy has become a member of the European Union and from the inventory perspective even more importantly, the member of the EMU (Economic and Monetary Union) and gone through two serious recessions with different origins. Our hypothesis is that these phenomena also have affected the Inventory to Sales Ratios at least in some industries, which again might have resulted in the volatility of the Finnish GDP growth. In addition, our paper will also look at the hypothesis that improved inventory management and flexible manufacturing systems might have contributed to lower Inventory to Sales Ratios at least in some industries. Our tentative results show that improved inventory management practices and the utilization of modern information technology really seem to be associated at least loosely with lower volatility.

In another part of the paper we will more closely analyze inventory investment behavior in different Finnish industries during the period of 1980 – 2009 using quarterly inventory data. By means of econometric investment models we will make an attempt to trace the most important explainers for inventory investment and to analyze their correlations with GDP basic components. We will focus on the role of monetary policy (measured by the real rate of interest) and business cycle expectations of economic agents within the Finnish economy.

Inventories in motion: A new approach to inventories over the business cycle

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I examine those inventories which arise 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, I overcome these difficulties using a non-linear solution algorithm. Simulating a monthly model, I aggregate the data to a quarterly frequency and find that the inventories model matches the aggregate data well. I then consider 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, I find little role for improved inventory management in explaining the decline in macroeconomic volatility. While the inventory management changes are useful to match aspects of the changes in inventory behaviour over the last 25 years, I conclude that the "Good Luck" hypothesis, namely, the idea that the decline in macroeconomic volatility is simply related to smaller and/or less frequent macroeconomic shocks, is a much more likely explanation for falling variance of GDP growth.

Keywords: Inventories, Distribution, Macroeconomic volatility

Inventory management of customer-stockpile in a competitive market when demand is interdependent over time

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In this study, we 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 future. The stockpile of the products generated by customers affects the demand in future periods. Therefore, the demand for each product not only is 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, we address not only the price and demand relationship 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. We use a deterministic dynamic program to calculate the equilibrium prices at the beginning of each period. By assuming that the market stockpile is public information, we show the existence of a unique Nash equilibrium. We next consider the case when the firms do not know the market stockpile. We then develop appropriate heuristics to calculate the optimal prices in each case. A numerical study is also provided to calculate the price levels in different scenarios and compare their performances.

INVENTORY MANAGEMENT

Spare parts classification and inventory management in durable goods industries - An empirical case study

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Objectives of study.

In durable goods industries, the implementation of an efficient spare parts management system is a complex matter due to the large variety of spare parts managed by a company, differing for lead time, demand patterns and costs parameters. To have an efficient control of spare parts, a useful approach is to sort spare parts in categories, through a multi-criteria decision making tool, and to develop specific inventory policies for each class. Unfortunately, the application of multi-criteria inventory classification in industries like household appliances and heating is limited, because the methods are often considered too complicated (Molenaers et al., 2010).

The aim of this paper is to propose a simple hierarchical multi-criteria spare parts classification method oriented to inventory management in order to obtain stock reduction and rationalization in a context with service level constraints.

Methods.

First of all a rigorous scientific literature review was carried out in order to identify a set of criteria for spare parts classification and their relationships with inventory policies (e.g. Huiskonen, 2001; Diaz, 2003; Kalchschmidt et al., 2003; Braglia et al, 2004; Niemi et Huiskonen, 2006; Cavalieri et al., 2008). A classification method and a framework for inventory management was then developed. The method was tested through an intensive case study, carried out in an Italian household appliances manufacturing company.

Results.

The proposed method for spare parts classification considers these dimensions: life cycle phase of final products, orders frequency, demand variability, parts value, process and supply criticality. The classification is then built composing the dimensions in an almost hierarchical fashion, obtaining 12 different classes. For each class and through an *ad hoc* simulation tool, a specific inventory policy (reorder and control) is proposed, with the aim to minimize the overall costs respecting a service level target. Comparing the new approach with the *as-is* scenario, in the case company we obtained a strong reduction of stock level and the related costs (on average 20%), also with a light improvement of service level (*fill rate*).

Conclusions.

The proposed classification method, performed without using complex mathematical methods, should help company managers in inventory management for spare parts, basing on quantitative and objective information and obtaining a significant improvement of performance.

Keywords: Spare parts, Multi-criteria decision making, Classification method, Inventory management, Case study

Supply chain coordination through quantity discount and credit options

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The focus of this study is the coordination of a two-echelon supply chain, consisting of a single buyer and a single supplier (vendor), dealing with a single product. The two coordination mechanisms examined here are: (a) a quantity price discount scheme and (b) a credit payment option with a specified credit period, offered by the vendor to the buyer, incorporated within a buyer/supplier contracting framework. Assuming deterministic conditions, we develop profit models for the buyer, the supplier, as well as the entire supply chain as an integrated entity, under various operating scenarios. These models allow the determination of the buyer's optimal ordering policy and retail price, as well as the optimal production/delivery policy and the wholesale price structure on the part of the vendor. Initially, for comparative purposes, individually optimal policies for the supply chain members are derived independently, without coordination. Subsequently, the coordinating mechanisms of price discount and credit (i.e. delayed) payment are incorporated in our models, towards developing individual, as well as jointly optimal policies. Our analyses indicate that either coordination mechanism, or both employed simultaneously, generates additional profit for the integrated supply chain. Furthermore, we provide a clear explanation concerning the sources of and incentives for attaining such additional profit and suggest means of sharing it in a fair and equitable manner by the buyer and the vendor. Based on the results of our models we are able to provide meaningful managerial guidelines for employing the quantity discount and/or credit payment terms for coordinating the supply chain, leading to higher profitability. We demonstrate our findings through a numerical example and perform a detailed sensitivity analysis with respect to some selected model parameters.

On the benefits of risk pooling in inventory management

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Inventory pooling is generally believed to be beneficial. This is mostly based on the assumption that the demand distributions of the individual locations are independent and normally distributed. Several recent publications have cast doubt on these benefits showing that, the savings due to pooling may approach zero as the demand variability increases. They argue that this inconsistency is partly due to the assumption of independent demands. However as we demonstrate even when the demands are independent there are vanishing benefits of pooling. This paradox about the true benefits of risk pooling is investigated. We consider risk pooling in a newsboy framework consisting of *n* identical locations, facing i.i.d. demands. We classify demand distributions into two categories: Category I that allow negative demand values and Category II that do not allow. Two measures of savings are utilized: the absolute (the reduction in the cost of operating the system due to inventory pooling) and the relative (relative to the non-pooled system).

Results: We show that the absolute saving increases with variability, and the relative saving stays fairly constant, when demand variability is low. However, this behaviour changes at higher variability. For Category II distributions the benefits in terms of both measures decrease once the coefficient of variation of demand at each location exceeds a certain threshold, and disappear as the variability grows. Also, under a given level of variability the benefits of pooling do increase with n.

These effects are due to the different operating regimes: as the variability is increased, the system switches from the normal operation to the effective shutdown (the system avoids taking the risk of too much inventories) and then to the complete shutdown (the system holds no inventory and accepts the full costs of unmet demand). The decrease in the benefits of inventory pooling is associated with the two latter regimes.

We analyze the behaviour of the inventory pooling benefits using the distribution free. We observed that the behaviour of savings due to pooling using the distribution free approximation is similar to the behaviour observed for other distributions in our numerical tests.

In Conclusion: Pooling allows the system to remain in the normal operation regime under higher levels of variability compared to the non-pooled system. Inventory pooling is, beneficial under all variability.

Keywords: Inventory management, Pooling, Newsboy

A life cycle model and two cases of OM development (Implications for inventory management)

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The paper analyses some aspects of the process of development of OM practice and the connected knowledge transfer. It describes 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 is presented and two illustrative cases are 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 will be analysed in detail.

Sustainable performance improvement and employee creativity in a lean warehouse environment

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This study aimed to identify sustainable ways to enhance the performance of logistic service providers, by implementing lean management principles and practices.Our theoretical point of departure was that a good match between workers' needs and work characteristics is a prerequisite for sustainable system effectiveness. To test this central hypothesis, we first used a modified version of Hackman and Oldham's (1976) Job Characteristics Model (JCM) to evaluate key dimensions of the fit between employees and their jobs. A survey was administered to a sample of 108 warehouse employees of a large Dutch multinational, strongly dedicated to the dissemination and implementation of the lean management philosophy (Warnecke & Hüser, 1995; Womack, Jones, & Roos, 1990). Especially the gap between the employees' need for creativity and the potential offered by the job to actually unleash creativity emerged as an important predictor of job satisfaction and turnover intent. Because lean management is aimed at the reduction of waste, and unused employee creativity has been identified as a major source of waste (Trent, 2008), this finding offered an interesting perspective on the intersection between person-work analysis and lean management.

In a follow-up study we used Value Stream Mapping to investigate where the use of employee creativity might be fruitfully employed in daily processes to reduce waste and achieve continuous flow, thereby improving system performance. Kaizen events in which employee creativity is critical to develop problem-solving capabilities in the service of lean management (Farris, van Aken, Doolen, & Worley, 2009) were organized, yielding suggestions to improve work practices. The most important suggestion turned out to be the visualization of both customer requirements and enhanced process performance. Future measurements will learn whether these practices have benefitted the long-term effectiveness of the warehouse. The practical implication of this study is that combining person-work analysis and value stream mapping has revealed areas for sustainable improvement of logistical processes, by solliciting and implementing suggestions that were both consequence and antecedent of increased worker motivation.

Keywords: Lean management, Logistics, Job characteristics model, Person-job fit, Value stream mapping

A spare parts model with cold-standby redundancy on system level

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Many of today's technological systems, such as aircraft or military installations are characterised by a high level of complexity and sophistication. The users of these capital assets usually require a guarantee of high availability, since the consequences of downtime can have very serious repercussions, e.g. economic loss or safety hazards. In order to achieve a high level of availability it is often profitable to replace a failed component by a new one and restore the failed component off-line. In this way, the downtime of a system can be limited to the replacement time only. Obviously, spare parts are needed in order to perform such a maintenance rule and thus the number and the type of spare parts that are available influence the availability of a system. However, from a cost perspective it is important to purchase only the spares that are needed to achieve the required availability level, especially since the repairable items are often very expensive. Deciding which components to purchase and in what amounts in order to achieve the required availability level against the lowest possible costs is therefore an important question. This paper presents a variant of a spare parts inventory model with cold stand-by redundancy on system level. Redundancy on system level implies that not all systems need to be operational in order to have the whole system operational. The cold stand-by feature implies that only the minimum required systems are operational. In order to determine a cost effective spare parts package such that in a cold stand-by redundancy situation a sufficient number of systems is operational for a specified period we extend the greedy heuristic, we know from the METRIC methodology. To compute the probability that the number of operating systems during the operational period is sufficient, we present both an exact, but time-consuming method, and a fast approximation method based on fitting the backorder distributions on the first two moments. This approximation method shows very small differences when compared to the exact method. Finally, we compare both methods to a simulation model in order to test the validity and impact of our modelling.

Keywords: Logistics, Spare parts, Inventory, System redundancy, METRIC

Tactical inventory and backorder decisions for systems with predictable production yield

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In addition to demand uncertainty, there is also the supply uncertainty in some systems. Traditionally the producer meets the demand with all products at hand. However, sometimes it may be more profitable not to sell all items on hand and allow some lost sales. In recent years, an alternative policy considering this fact has been improved and called as tactical inventory, where the producer have the option to reserve some of the products for future periods even if there is any unmet demand at current period.

We consider a manufacturing system with stochastic demand and predictable production yield. The manufacturer has predetermined prices and limited production capacity in each period. The producer also has the option to save some inventory for future periods. The demand that is not met is lost or may be backordered for only one period. Our objective is to maximize the expected profit by choosing optimal production, save and backorder amounts in each period. We formulate this problem as a Markov Decision Process where the state of the system is represented by the net inventory and the efficiency parameter.

We analyze and show that the optimal policy is of a modified produce-up-to type. Optimal policy is characterized by three parameters (Y; S; B) where Y is the produce-up-to level, S is the reserve and B is the backlog-up-to levels. We prove that we only have two candidate policies that can be optimal; save-inventory policy and backlog-demand policy. Further, we analyze and present how the optimal policy is affected by changes in the production yield. The production yield of the current period is shown to have no impact on the optimal policy for the remaining periods. In the save-inventory strategy the optimal production and reserve decisions are non-increasing while in the backlog-demand strategy the optimal production and backlog decisions are non-decreasing in the production yield of the following period.

Application of on-demand inventory control software to fast-food chain

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Inventory connects and balances each stage in an autonomous supply chain. Some traditional methods for inventory control are statistical approaches and thus would not be adaptive to follow real fluctuations of demand in the modern society. The fast food chains are providing foods to the suddenly appeared clients with rapid operation. They are usually facing daily demand fluctuation because of weather conditions or discount tactics of the rival chains. They rely on the many food material suppliers who are willing to produce with larger lot size and deliver whole lot quantity to the fast food chain's DC. Hence DC of fast food chains holds huge quantity of inventory in their backyards. Sometimes inventory amounts 6 months' average demand quantity. That is not profitable so they need to reduce their inventory as much as they can without shortage of food material replenished by their suppliers. We introduce a look-ahead method for on-demand supply by the progressive control of pull type in 2005, and apply a new method for inventory control at each stage in supply chain. This new method is an innovative/stochastic approach to supply chain controls and provides an effective tool for demand-to-supply management in supply chain. This tool is named ODICS (On-demand Inventory Control System). Popular and well-known inventory control tools are based on the forecasting demand and calculating appropriate order/produce quantity in order to minimize the gap between the calculated demand and observed demand. Actually, this conventional idea has not demonstrated desirable result. We have looked from different angle. That is past demand trend may not explain future trend. The key technical concept of ODICS is the introduction of moving standard inventory by the newsboy problem and Matsui's logic for its look-ahead. The characteristics of this new method mainly involves a sequential decision of order quantity/time in real-time. There is a good possibility to decrease inventory in fast food chain DC and their suppliers by adopting ODICS. Several case studies are experimented by using the ODICS, which used by fast food chains and their supplying manufacturers. Notable reduction in inventory is shown in all executed cases.

Keywords: SCM, Progressive control, Newsboy model, Fast food chain, Matsui's logic

Managing lead times and inventories in global supply chains

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The objective of the study is to analyse which supply chain management (SCM) practices lead to higher performances - in terms of lead time and inventories - according to different global supply chain configurations.

The process of internationalization of companies is widely known and it has been significantly fostered in the last twenty years by all those factors (communication, logistics, markets, etc.) considered beneath the concept of globalization.

However, given the longer distances, global supply chains are supposed to make lead times longer and more variable with a negative effect on inventories (Bozarth, 1998; Handifield, 1994; Kotabe et al., 2009). However literature about global supply chain and performances is controversial with many examples of companies either successful or unsuccessful in their global supply chain strategies (Meixell and Gargeya, 2005; Golini and Kalchschmidt, 2009).

This lack in literature depends also on the fact that companies may adopt different global supply chain configurations (Cagliano et al., 2008) but little research has been done about which SCM practices (i.e. how to coordinate and manage sourcing, manufacturing and distribution activities on a global scale) work better in different SC configurations to reach higher performances.

Materials and Methods:

The research goal is pursued through a survey methodology, by means of the fifth release of the International Manufacturing Strategy Survey (IMSS) with data collected in 2009. The database provides evidence on more than 600 companies in the assembly industry (ISIC 28-35 sectors) across 19 countries.

Results:

Preliminary findings show that the companies adopting different configurations use different management practices with diverse outcomes. Nevertheless there are some practices that are always beneficial in enhancing particular performances. For example, performing just-in-time with suppliers enables companies even with different global configurations to reduce procurement lead times. Finally there is evidence that a more complex and globalized supply chain does not cause necessarily worse performance if correctly managed.

Conclusions:

From our viewpoint the paper significantly contributes to the research about global SCM providing interesting insights for practitioners too to orient their SCM investments according to their companies' global configuration.

Costs and opportunities of centralizing/automating picking activities in supply chains

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The paper deals with a multi-echelon inventory/distribution system where order picking activities have a significant impact on the system performance. As an example, this situation is typical in the food and beverage industry, where multi-item pallets are delivered to the customers (e.g. catering businesses) with high frequency and low volumes per delivery.

In the most of cases, picking activities are labour-intensive activities, manually executed as closer as possible to final customers. Thus, it is necessary to set up intermediate facilities where picking activities are performed just before delivery. This leads to decentralized supply chain configurations where intermediate actors operate between the central warehouse and the customers.

Nevertheless, in recent years the evolution of handling technologies has enabled the introduction of automated picking systems. Such systems can prepare multi-item pallets at a speed consistently higher than humans, so they make it possible to centralize picking activities and re-design the whole supply chain in a way as to reduce the number of intermediate actors and their related costs.

From here the need to develop cost models and derive cost figures to assess in what conditions such a supply chain re-design is profitable.

The proposed work is done in collaboration with a distribution company operating in the beverage field and addresses an actual case. A supply chain configuration consisting of three levels with decentralized picking activities is redesigned so as to allow a centralization of the picking and a transformation of the second level in simple cross-docking points. Impact of such a change in transportation costs, inventory levels, demand variability propagation and facility owning costs is addressed, and the most critical aspects are emphasized.

The comparison between the centralized and the decentralized configuration is carried out by developing an analytical model for cost computation. The main differential operative costs (e.g. transportation costs and stock holding costs) are computed and some quali-quantitative considerations are pointed out. Finally, the effective benefit of the centralized configuration can be obtained by comparing cost savings and investment costs.

Keywords: Supply chain, Picking activity, Cost model, Inventory centralization, Automation.

Consignment stock policy for a two-level supply chain with defective items

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The firms in today's competitive markets have been looking for ways to perform effectively. As a result of this struggle, we notice practitioners and researchers in the field of supply chain inclining more and more towards better coordination. A number of strategies have been used to boost such coordination, e.g. quantity discounts, delay in payments etc. One such strategy used in recent years to coordinate supply and stock management, is consignment stock. This strategy is becoming popular as it provides an alternative approach to stocking and controlling inventories, which is in the mutual interest of a buyer and vendor. This policy tries to reduce the inventory stock at the vendor's end as vendor uses the buyer's warehouse to store its products. On the other hand, the buyer withdraws the material from this warehouse as per its consumption and pays the vendor accordingly. This informs the vendor about the consumption of its products, immediately. To visualize the benefits of this coordination, it should be noticed that vendor and buyer have traditionally been trying to estimate their economic lot size independently, i.e. through EPQ and EOQ respectively.

Most of the literature on inventory/supply chain modelling has unrealistically assumed the production lots to be defect free. A recent study extended the basic EOQ model for the case where each lot contains a random fraction of defective items. It assumed that this fraction has a known probability distribution. It also assumed that each lot goes through complete screening and the defective items are all separated and sold at a discounted price in each cycle.

This paper considers a consignment stock policy in a two-level supply chain where a fraction of the vendor's product is defective. An analytical model is developed to depict this scenario and the numerical results from this model are discussed. Later, they are compared to those of prominent studies in the literature for additional insights.

An optimal truck and train transportation of containers

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In this paper, an intermodal transportation problem that involves one-depot and one-station with time windows at both origins and destinations is dealt with. 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. There are four kinds of containers: inbound full, inbound empty, outbound full, outbound empty containers to be transported only by truck or by truck and freight train together. Inbound full containers mean freights to be delivered from terminal to customer's locations or depot and outbound containers mean freights to be delivered to the terminal. In this paper, we assume an inland transportation network with one terminal, depot, train station, and customer places for inland transportation of one type of containers. The capacity of trains is assumed to be infinite and the time table of trains is given. A meta heuristic algorithm based on tabu search, is proposed to find the optimal solution to minimize the total transportation cost. The numerical results of the proposed method is compared to the solutions obtained by CPLEX.

Keywords: Time windows, Intermodal transportation, Meta heuristic, Freight train, Tabu search

An ordering policy for an assemble-to-order system with different review periods

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In real-life supply chains, individual items have their own lot sizing and lead time constraints based on contracts with suppliers or production process characteristics. Coordination of release decisions across multiple items is thereby not an easy task. In literature convenient assumptions are made, such as equal lot sizes for items, equal review periods or nested lot sizes and nested review periods. One of the consequences of these assumptions is that upstream items and long lead time items have larger lot sizes. Unfortunately, in practice, simple and cheap materials have short lead times whereas complex and expensive materials have long lead times. On top of that the EOQ of complex and expensive items implies that such items should be ordered more frequently then cheap items. Thus, there is a need for control policies for assembly systems consisting of expensive, frequently ordered long-lead-time items and cheap, infrequently ordered short-lead-time items.

For simplicity, we consider a single-echelon assemble-to-order system where a single item is assembled from two components whenever customer demand occurs. Customer demand is stochastic and unsatisfied demand is assumed to be backordered. One component has a long lead time and high holding cost while the other one has a short lead time and relatively low holding cost. Shipment lead times are both assumed to be deterministic. We further assume that the inventory levels are reviewed periodically and review periods are given. Due to its high holding cost the expensive component has a short replenishment interval. On the other hand, the cheap component has a long replenishment interval because of restrictions from its supplier.

We define the replenishment interval plus the lead time of an item as the uncertainty period of the item. Through mathematical analysis, we observe that the optimal order quantities depend on the difference between the uncertainty periods of both components. Based on this difference we define reasonable ordering policies, where one stock point is controlled by an order-up to policy and the orders for the other stock point are synchronized. The policy parameters are optimized with respect to the expected cost per period and the performance of the policy is investigated.

Keywords: Inventory management, Assemble-to-order system, Stochastic demand, Fixed replenishment intervals, Heuristic

Dual sourcing with capacity reservation and stochastic spot market prices: Optimal procurement strategy and heuristics

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Purchasing based on capacity reservation contracts and buying on the spot market are two alternative purchasing practices. Spot market purchasing is a benefit in case of low spot market prices or insufficient reserved capacity, and the capacity reservation contract is an operational risk hedging for high spot market price incidents.

We analyze the combined sourcing decision for several periods under stochastic demand and random spot market price fluctuations. It has to be decided - period by period - which quantities to procure from the two sources. The combined procurement strategy has to protect against risks of insufficient demand fulfilment and exploit the benefits of forward buying in periods with low spot price levels. Additionally, a long-term decision has to be made regarding the reserved capacity level to be fixed with the long-term supplier to create sufficient protection for high spot market price incidents. The decision on capacity reservation has to take into account the short-term capacity utilization of each source which itself depends on the available long-term capacity. Thus, we face a highly complex interdependence of long-term and short-term decisions under uncertainties in demand and spot market price. We model the above decision problem as a stochastic dynamic optimization problem and analyze the optimal procurement strategy by means of stochastic dynamic programming. Thereby, we are able to prove that the optimal procurement decisions can be made based upon a quite complex three-parameter policy with a fixed order-up-to level for ordering from the long-term supplier and price-dependent order-up-to levels for short-term spot market procurement. The third policy parameter is the capacity reservation level. It is very cumbersome to numerically calculate the optimal values of all policy parameters, especially the price-dependent order-up-to levels. Therefore, we develop a fairly simple heuristic approach for determining all parameters and parameter functions which is based on the solution of appropriately adjusted newsvendor problems and on the results from a related simplified base stock policy. Finally, we present the managerial analysis and a comprehensive numerical study showing that our heuristic policy performs very well for a wide range of problem instances.

Assessing the impact of RFID temperature data logger on perishable inventory management

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Perishable items are sensitive to temperature in which they are handled and require special storage conditions to preserve their freshness. Typical examples of such products are chilled and frozen foods, pharmaceutical products and blood, etc. Recently, a new technology called Time temperature (TTIs) has been developed and seemed to be able to evaluate the shelf life of perishables. Coupled with an RFID tag, this technology provides the remaining shelf life of items by recording the time-temperature history. Although the wide qualitative benefits of using such technology, suppliers does not recognize its ability to reduce spoilage. Perhaps, the main reasons of that are the limited diffusion of TTIs and the lack of quantified benefits. We aim in this paper to assess the impact of using TTIs on inventory management. To do so, we firstly formulate a periodic review inventory model for single item with random lifetime. The behaviour of this inventory system is modelled as a Markov process and characterized by the stationary regime. This model allows us to obtain the exact expression of the average total operating cost under First In First Out (FIFO) issuing policy. Secondly, we deploy TTIs and deplete the inventory based on Least Shelf life First out (LSFO) policy. As a consequence, we can compare between the FIFO and LSFO policies. We believe that LSFO outperforms the FIFO issuing policy but this performance depends on the acquisition cost of TTIs tag. Finally, we investigate the impact of the lifetime distributions on the overall system performance.

Optimal time-based consolidation policy with price sensitive demand

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We consider a single-item inventory system where shipments are 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, we consider price sensitive demand and develop an optimal time-based consolidation. The objective is to compute the optimal price, replenishment quantity and shipment cycle to maximize the total profit. The long-run average profit is computed and the optimal properties are obtained. We prove that the long-run average profit is 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 is provided. Thus, by substituting the price with replenishment quantity and shipment cycle in the profit function, the problem is reduced to compute the optimal replenishment quantity and the optimal shipment cycle only. We prove that the average profit function is a concave function of shipment cycle and obtain an upper bound for the optimal replenishment quantity. Using the optimality conditions, we develop a search algorithm to obtain the optimal values of replenishment quantity and shipment cycle for the proposed policy. The computational complexity of the proposed search algorithm is polynomial. In order to compare the performance of the proposed policy and existing consolidation policy, we conduct extensive numerical experiments and compare the performance in terms of the resulting price and profit. The results from numerical experiments show that average profit significantly increases using the proposed policies rather than the existing model without pricing.

Keywords: Pricing, Inventory management, Transportation management, Time-based consolidation policy, Quantity-based consolidation policy

The impact of human resource practices on lean production

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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 focuses 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 is also made in order to derive the implications for practitioners who are responsible to promote lean production or lean supply chain.

Keywords: Lean production, JIT production, Human resource management, Empirical research

Multi-criteria ABC inventory classification using cross-evaluation in DEA

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Enhancing the performance of a production process has been an important task for the purpose of effective control and planning in very keen competitive environments. In general, Data Envelopment Analysis (DEA) has been widely applied to evaluate the relative efficiency among production organizations. DEA is a linear programming technique which evaluates relative efficiency of a homogeneous set of DMUs (Decision-Making Units) with multiple inputs and outputs. DEA can also be a tool to find a reference that an inefficient DUM should benchmark based on the efficiency score. A production system, in our paper, is composed with multiple production units interrelated with each other in such way that outputs of one unit may influence input of another, and that efficiency of each unit also influences that of a whole system. In particular, inventory level is one of the critical factors for the efficiency of each unit, and the inventory information of the production units are inter-related each other in that inventory of a unit influences that of others. Traditional application of DEA has a limitation that it cannot consider relationships between production units in the system including inventory information, and it cannot consider the relationship between a unit and the whole system either. For such a reason, the efficiency score of DEA may not properly represent the aggregate performance of the processes of a production system and does not show which unit process causes the low efficiency of the system. In order to solve this problem, a network DEA model has been proposed. So far, a network DEA model considers series and parallel process structure of a production system. In a parallel structure of production system, semantic of the structure may be very complex. That is, the split semantic can be interpreted as either of 'OR' or 'AND' cases. And each semantic may also be classified into variants based on the relationship of input and output. If we consider inventory from the information perspective, the input/output factors may be duplicated which forms 'OR' relation in parallel unit case. However, traditional network DEA has been able to deal with only 'AND' case of parallel structure. In this paper, we suggest an extended network DEA model, taking into account the interrelationships of inventory information among the unit processes within a production system. In order to achieve this purpose, we provide a mathematical formulation which can evaluate the efficiency of 'OR' case in a parallel structure of a production system. By applying our model to the mixed model production system which is beneficial to reduce the inventory accumulation, we can measure the efficiency of each unit process considering inventory reduction. Also we can analyze how much a unit process contributes to the efficient management of inventory level.

Keywords: Network DEA, Production system, Efficiency, Inventory

Stock rationing with multiple-unit demands and varying unit size

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We consider a periodic-review base-stock control system with lost sales and deal with the problem of optimal stock rationing between two consecutive replenishment opportunities in presence of multiple demand classes. We assume 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. We solve the problem 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.

Keywords: Inventory rationing, Revenue management, Dynamic programming, Parametric mixed-integer programming

Simulation based analysis of buffer configuration and loading policies: An example from the glass industry

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In our research study we provide an analysis of buffer configuration and loading policies based on empirical quantitative modelling. Our study is motivated by the characteristics of the glass manufacturing industry. We aim to find a feasible solution that can be applied within an empirical setting, i.e., our modelling approach overcomes the disadvantages (response time, etc.) of optimization based on mathematical programming. We analyze the dynamic dependencies between buffer configuration and loading policies.

Inventory management is challenging because it directly impacts both cost and service level. On the one hand, there is a minimum required inventory to hedge uncertainties. On the other hand, problems such as increased lead times occur in case of excessive inventory. Therefore, it is necessary to figure out the right size of inventory needed by the system. We conducted our study in a glass production company. Based on increased customer requirements and demand, the company needs to increase its capacity and reduce its flow-time. We analyzed the impact of different buffer characteristics (size, etc.) and loading policies on throughput as well as flow-time. The number of products on the oven platforms and their orientation is a key driver for process performance. Our goal is to increase the loading of the oven platforms facilitated by multiple buffers. Glass sheets are classified and allocated based on size to a buffer in front of the bottleneck station. This provides the possibility to load efficient combination of glasses on each platform. Based on a process simulation model we are able to take into account the dynamic dependencies. In particular, we will compare the performance of the actual situation with the process improvements based on WIP, throughput, machine utilization, and flow-time.

Our analysis provides evidence for performance improvement without additional capacity investment. We observed that classical buffer size optimization approaches are not applicable because of problem complexity. We demonstrated that a combination of modified loading policies and usage of multiple buffers provides the capacity of handling additional input. Our approach can be generalized to manufacturing processes in different industries with the same characteristic, i.e. with a platform loading problem related to delay station (items get delayed at an operation) that is the bottleneck of the system.

Keywords: Inventory, Flow-time, Throughput, Loading policy, Simulation

Joint ordering and inspection policy for a multi-period inventory system subject to shrinkage errors

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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. We consider an infinite horizon, single-stage, single-product periodic-review inventory in which inventory records are inaccurate. We assume that inventory inaccuracies are introduced by shrinkage type errors that occur within the store. We assume that an inspection policy is performed each a finite number of selling cycles. We propose two situations permitting to manage the joint ordering and inspection policy based on the information we have on shrinkage errors. The comparison between the two situations permits us 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.

A fractal echelon approach for inventory management in supply chain networks

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A major issue in supply chain inventory management is the coordination of inventory policies adopted by different members in a supply chain including suppliers, manufacturers, distributors, etc. This paper presents a fractal-based approach for inventory management in order to minimize inventory costs and to smooth material flow among supply chain members while responsively meeting customer demand. Within this framework, each member in the supply chain is defined as a self-similar structure, referred to as a fractal. In addition, we define a concept of an echelon in a new way as a fractal, which is different from the one found in the literature. A fractal-based echelon does not indicate a functional level or composition of supply chain members but indicates a group of multi- or hetero-functional fractals. The basic fractal unit (BFU) consists of five functional modules including an observer, an analyzer, a resolver, an organizer, and a reporter. Application of a fractal concept into inventory management makes it easy to intuitively understand and to manage supply chain inventories because similar functional modules can iteratively applied to an inventory management system. Furthermore, we can use intrinsic characteristics of a fractal such as self-organization, self-optimization, goal-orientation, vitality and dynamics as well as self-similarity. In specific, we apply a fractal concept into a vendor managed inventory (VMI) model where a supplier (often a manufacturer) assumes responsibility for maintaining inventory levels and determining order quantities for its customers (often distributors or retailers). Among functional modules in BFU, we develop mathematical models of an analyzer and a resolver to effectively manage supply chain inventories. For facilitation of coordination or cooperation between fractals, in this paper, we apply multi-agent technology after presenting behaviour models of agents.

Keywords: Fractal echelon, Inventory management, Supply chain management, Vendor managed inventory (VMI), Multi-agent technology

The inventory management of materials in hospitals: The case of nonwoven medical fabrics for single-use

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Inventory management techniques have been deeply studied in many industries. Today there is a growing interest in considering such techniques also in a very important field: the healthcare management. Inventories in healthcare are very costly and its management needs to be optimized. In the paper the inventory management of a very important material is considered: the Nonwoven Fabrics for Single Use. Even if this material is not very costly, there are huge quantities that are used and its importance is extreme. The availability is essential for allowing critical operation such as surgery. Thus, service level constraints have to be considered when deciding on the replenishment policy of such a material. In the paper a replenishment policy based on the Vendor Management Inventory technique has been developed in order to respect service levels constraints while minimize costs associated to replenishment, storage, and reverse logistic flow of used nonwoven items. The policy has been evaluated through a simulation study, and compared to the actual policy adopted in a real case.

Incorporating future consequences of an order quantity decision: A two-period newsvendor model

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In the newsvendor model a retailer has to determine the order quantity of a certain product facing random demand. Maximising the expected profit yields a quantile of the probability distribution of demand as optimal ordering policy. In many cases empirical and experimental findings do not coincide with this analytic result. In situations according to the newsvendor model researchers observed different order quantities. These findings suggest that the expected profit is not the only criterion decision makers refer to for determining the optimal ordering policy.

In the following, the consequences arising out of underage and overage constitute such additional decision criteria. Though the classical newsvendor model rules out both postponement of unmet demand and stocking of remainders, the order quantity decision has wide influence on the expected profits of forthcoming periods: Large underage would annoy customers and thus diminishes future demands whereas huge overage might cause major loss making future profits impossible by means of bankruptcy.

On the one hand these long-term consequences can be regarded by constraints concerning the probability or the expected extent of underage and overage. On the other hand their impact on future profits can be modelled directly in a multi-period framework. The latter approach will be implemented here, restricted to two periods. Thereby attention is turned to the consequence of underage only.

The model incorporates both the positive influence of the first period order quantity and the negative influence of the first period value of demand on the second period value of demand respectively. Hence in difference to the inventory literature the chosen approach explicitly does not assume stochastically independent demands across periods.

The order quantity decisions are modelled to be made successively. Maximising the expected capital value of the profits in both periods leads to an optimal order quantity in the first period that is bigger than in the single-period case. This result corresponds to intuition.

The introduced model provides a tool for incorporating a future-oriented criterion which many decision makers intuitively would regard as well. An approach considering the future consequence of overage simultaneously is object of actual research.

Keywords: Two-period newsvendor model, Dependent demands, Underage

A study on the benefits of vendor managed inventory with competition

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Empirical evidence has shown that collaboration efforts among business partners lead to supply chain performance improvement. Among these collative initiatives that have gained attention in research and practice is vendor managed inventory (VMI) system. Basically, the rationale for implementing VMI is that by pushing the inventory decision making further upstream in the supply chain, the vendor will be in a position to make a better decision for the entire supply chain through information sharing, centralized replenishment, collaborative planning, and risk pooling. However, due to the inherent complexity of interactions within supply chain which encompasses demand variations, supply disruptions, competitions, and information asymmetry, capturing the benefits of VMI initiatives is a big challenge. One of the primary objectives in the implementations of a supply chain integration strategy such as a VMI is to develop an incentive compatible mechanism whereby every stakeholder across supply chain could align with, and at the same time, improve the overall supply chain profitability. This research develops a simulation model for VMI to investigate relationships between various supply chain parameters and performance at a global as well as at a local level. In particular, we examine effects of varying structural parameters (such as variations in demand, cost structures, and the homogeneity of retailer) and policy parameters (inventory policies implemented) when there are competing retailers and the final demand is random. Under competition, end customers can choose to shop at other retailers when faced with stock outs. Basically, shortages at each retailer will be treated as lost sales and not backorders unless all retailers run out of stock simultaneously. VMI results will be compared with those of a locally managed inventory (LMI) system, which will be used as the base case. Discussions of results will focus on a number of critical aspects of VMI as a collaborative initiative. Initial numerical results revealed that (i) the benefits of VMI is more pronounced when vendors supply heterogeneous retailers (in terms of demand distribution) under competition and (ii) that a joint replenishment practice is more effective with greater level of retailer heterogeneity. Also, practical aspects of VMI will be addressed to gain managerial insights into how its implementation could lead to a long term sustainable advantage for business.

Keywords: Vendor managed inventory, Information sharing, Simulation, Integration

China's evolving supply chain infrastructure: Hardware and software

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While China's industrial output continues to grow in spite of world-wide industrial slowdowns, the status of the country's supply chain infrastructure becomes an increasingly serious issue. China's governmental programs are already well underway. Many initiatives complement projects underway, others are developing to meet future needs. To date, publicized initiatives have focused first on hardware – roads, rail, ports, power, vehicles… to support the country's development

Concurrent with these initiatives is systematic development of the country's governance and ideological structures – the software necessary to support the country' Reform and Opening Up initiative.

This presentation will describe the fundamental supply chain hardware and software changes already underway within the People's Republic of China, from roads and rails to fundamental amendments to the Country's Constitution.

Revisiting procedures for the deployment of items and their safety stocks in multi-location, multi-echelon, multi-product supply chains

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As supply chain networks (production-distribution systems) become more complex—in terms of the multiplicity of locations, echelons, and products—it has become increasingly difficult to design and/or optimize such networks. Key strategic decisions include the number of echelons to employ the number and locations of facilities in each echelon, and the allocation of customer demands to upstream supply points. Key tactical decisions include where to manufacture each item, where to hold inventories of each item, and how much inventory of each item to hold at each assigned stocking location.

Excellent models exist to help in the design and optimization process (see Melo, Nickel and Saldanha da Gama (2009) for a comprehensive review). But inventories are usually only dealt with in an aggregate sense for the most part. Where inventories are modelled in more detail, broad simplifications are often accepted. Excellent models also exist for selecting and locating inventory cycle and safety stocks in a network that is already fixed. Graves and Willems (2000) (2003) formulate a multi-echelon inventory model and solution procedures for locating individual item safety stocks in a supply chain where all the locations are fixed and in place. Currently there is lacking in the literature a robust procedure for simultaneously designing multi-echelon, multi-location, multi-commodity networks and determining what safety stocks of which items should be stocked at each location that is selected for the designed network. This paper suggests ways in which this shortcoming might be remedied. We propose various procedures that could be used in solving the simultaneous supply chain design and inventory deployment problem in practical applications.

The capabilities of manufacturing companies to operate in virtual supply chains

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Synergic effect of larger complexity and growing dynamics of business processes result in discontinuity of development of businesses, particularly in the environment troubled by economic recession and current shrinking business opportunities. Although the new economics and social order is not quite clear yet, it should be worthwhile to revisit the idea of managerial issues of virtual supply chains that have become an accepted business concept. The virtual organization became one of the symbols of modern economic and social development, however, it still remains one of the least understood and the most discussed concepts. Supply chain can be described as a specific form of a virtual organization with its all characteristics. Virtual supply chains are frequently identified with e-business, computer communication and digital products. Within the framework of organization theory a virtual supply chain is more than that; it is an organization that is subject to constant changes, demonstrating a specific potential when required, overcoming time and space barriers. Virtual supply chains could be described by such attributes like temporary character, focus on customers, geographical dispersion, intensive support of IT systems, network structure and an extensive use of key competencies of their members. The proposed paper defines the concept of a virtual supply chain (VSC) and indicates how its characteristic features. Temporary character of VSC allows for collaboration of firms during specific required ventures. Members of VSC can operate in different dynamic business networks and activate new ones according to emerging business opportunities and specific customers. VSC must have an extensive ITC support to be comparatively independent of location aspects of operations. Operational structures of VSC drive apart from traditional hierarchical structures towards horizontal and cooperative relations in the networks based on expertise and abilities of their dedicated members. The paper will attempt to answer the following main research questions:

RQ1: What are the actual main factors contributing to the abilities of manufacturing companies to become a part of virtual supply chain?

RQ2: What are the significant attributes of producers demonstrating different levels of adjustment to operate in virtual supply chains?

The research has been carried out in large number of manufacturing companies operating in European, Asian and American supply chains. The necessary methodology and statistical analyses have been employed in a research process. In order to identify the criteria of virtual abilities required from manufacturers an exploratory factor analysis has been conducted. In a second step of the research a cluster analysis has been performed. The conclusions obtained on the basis of empirical study enabled to conduct comparative analyses of selected attributes characterizing the virtual abilities within extracted clusters of manufacturers.

Keywords: Virtual supply chains, Logistics management, Virtual capabilities

Economic production quantity model with immediate rework and partial backordering

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Multi products single machine production systems with certain or uncertain breakdowns and rework process have become a popular subject of research in inventory management. In this research, economic production quantity (EPQ) model with rework process and partial backordering is studied. The aim of this paper is to determine the optimal cycle length, optimal shortages and optimal order quantities of each product so that the overall cost is minimized. The convexity of the objective function is proved, and two numerical examples to demonstrate the applicability of the proposed model in real-world environments are provided. The economic production quantity (EOQ) model was first introduced several decades ago. It is a mathematical model that can be used to derive an optimal production quantity that assists corporations in minimizing total inventory costs. One of the extensions for this model deals with the rework on an imperfect product. Chiu (2010) extended an EPQ model with robust planning in optimization, specifically in determining the optimal run time for production system that is subject to random breakdowns under abort/resume (AR) control policy and failure in rework. Haji et al. (2009) extended the optimal solution for an inventory problem consisting of a single machine which produces defective items. We assume that no shortages are allowed and all defective items are to be reworked. Setup cost for rework and waiting time of defectives are considered. In this research, an EPQ model with production capacity limitation, breakdown, immediate rework, and partial backordered quantities was developed. The primary aim of this research is to determine the optimal period lengths, backorder, and order quantities. The objective function of the proposed mathematical model was proved to be convex. Three numerical examples with fifteen products were used to illustrate the implementation of the proposed method. Finally, sensitivity analysis is performed to demonstrate the applicability of the proposed methodology and to provide some managerial insights for practitioners.

Keywords: Inventory, Partial backordering, EPQ, Rework, Limited production capacity

Distribution-free inventory management

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We study inventory management problems where demands are revealed incrementally and procurement decisions must be made before the demands are realized. There are neither probabilistic distributions nor non-trivial bounds to characterize demands. Using competitive analysis, a framework borrowed from Computer Science, we approach the inventory management problem from a worst-case perspective, which leads to risk-averse decisions. We consider two cost-minimization problems: (1) perishable products with lost sales and (2) durable products with backlogged demand. We design frameworks, 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 that we study consists of designing the procurement strategy for a single perishable product over a finite planning horizon with period-dependent costs. We provide three examples of how to apply our 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. In the first two cases, period-dependent *ranges* of procurement quantities are derived, which depend on problem data and exogenous preferences. These ranges provide an inherent adjustability that allows a decision maker flexibility in determining a procurement decision. Indeed, our third example discusses how these ranges could be added as constraints into a more traditional inventory model, such as an MRP system, to improve the quality of the solution.

The second problem that we study consists 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 is backlogged for future periods. We apply our framework to provide an in-depth example of a Make-to-Order strategy that identifies the best times to fulfil backlogged demand. We also design and execute a Monte Carlo simulation experiment to study the practical performance of the Make-to-Order strategy.

Keywords: Distribution-free, Inventory management, Dynamic lot-sizing, Worst-case analysis, Risk-averse

Determining the number of stacks in a mixed block stacking bay considering relocations

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This paper addresses 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 addresses how to estimate the number of relocations during the retrieval process in various situations. The retrieval probability and the storage probability are defined formally and it is shown how they are estimated from data on the duration of stay and the retrieval frequency of each type of unit loads. Next, it is discussed how to determine the optimal number of stacks in a bay considering handling and space costs. Three cases are 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. Numerical experiments are performed to illustrate the optimizing method.

Keywords: Relocations, Unit load, Storage yard, Block stacking storage system

Simulation-based spare part optimization in multi indenture systems

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In this paper, we deal with a spare part optimization problem of multi indenture systems. The multi indenture system has a hierarchical structure with multi levels and repair of upper items means replacement of lower items. In addition, we assume a multi echelon repair organization which is typical in modern electronic device area. We consider total operation cost and service rate to keep proper spare parts. The service rate is the proportion of customers of whose failed products are repaired within the given time period. Simulation is used to estimate the total expected operation cost and service rate. Simulation model is proposed and some numerical examples are also studied.

Keywords: Multi indenture, Echelon, Operation cost, Service rate

The bullwhip effect and the end of period effect: Empirical evidence from the personal care sector

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The bullwhip effect is a classic topic in supply chain management and has been widely investigated by literature. Though theory has explained the bullwhip effect and developed remedies for it a few years ago, it is still present in many supply chains.

A second stream of literature investigates the so called End-of-Period-Effect that is the effect of the end of a period (e.g., year) on the variations of demand and performance. These two effects are quite interlinked since the latter might be the root cause of fluctuation in the upper echelons of the supply chain. Toward the end of the "period"

This paper empirically investigates how the end-of-period-effect might create the bullwhip-effect. Data refer to the Italian subsidiary of a multi-national company that operates in 130 countries.

Analyses are performed on a set of demand observations: For 9 consumer goods, at the week level over a period of 52 weeks. Demand is recorded both at retail level and wholesale level.

Objectives: This dataset is investigated to:

1) Empirically measure the bullwhip effect that is the extent to which demand variability increases upstream in the supply chain.

2) Evaluate whether the strength of the bullwhip effect differs across products.

3) An Investigate the reasons behind such differences.

Empirical results: Findings show 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).

This finding leads us to the last question: why do we see such a wide range of variations?

We tried to explain them through product features, but failed. However, the very nature of demand proved to be a powerful explanatory variable: for products with a very seasonal consumer demand, the bullwhip effect is negligible (e.g., solar creams). On the contrary, for staple products with a relatively stable demand we observe a rather significant increase in variability in the upstream stage of the supply chain.

The full paper illustrates empirical results in details and discusses why the Bullwhip effect is so different in these two sets of products.

MATHEMATICAL MODELS OF INVENTORIES

Single-cycle policies for a single-vendor two-buyer system with permissible delay in payments

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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. We can find many references 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. We assume 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 we formulate and solve the problem in terms of single-cycle policies.

Keywords: Inventory, Permissible delay in payments, One-vendor two-buyer system, Single-cycle policy

Storage assignment rules and travel time minimization in an order picking system

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Order picking is the process of retrieving products from a storage area in response to a specific customer request. Advanced approaches to improve order picking efficiency can significantly reduce customer response time in a supply chain system, decrease the overall logistic costs and improve customer service level. In particular, the storage assignment problem deals with the assignment of products to storage locations: which is the best amount of space to each stock keeping unit - SKU? which is the best location for the generic product?

Bartholdi and Hackman (2007) discuss about the first issue in order to reduce the number of restocks in a fast pick (forward) and bulk storage (reserve) picking system. The aim of this study is to develop and apply a systematic procedure for the minimization of pickers' traveling time and distance in a forward-reserve picker to part order picking system in accordance with different strategies for the determination of the storage space in the fast (primary) pick area. The proposed procedure, models and tools are applied to a significant case study, and the obtained results coming from a what-if analysis are compared in order to identify effective guidelines for practitioners and logistic managers of industry.

Keywords: Storage assignment, Order picking system, Optimization, Travel time

Dual-sourcing in two-echelon inventory systems with fixed expediting costs

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Recently the literature has shown a renewed interest in models of dual-sourcing inventory systems facing stochastic demand. In these models there is a regular supplier with a relatively long lead time and an emergency supplier with a shorter lead time but a higher price per unit purchased. In such system ordering policies aim to minimize inventory holding, backlogging and per unit emergency ordering costs. For periodic review systems with an arbitrary lead time difference between the fast and slow supply mode, the optimal policy structure is known to depend on the entire vector of outstanding orders. For these systems heuristic policies with an appealing structure have been suggested such as the dual-index policy that was shown to perform close to optimal.

The dual-index policy is a type of base-stock policy that tracks an emergency and a regular inventory position. The emergency inventory position includes the net inventory (on hand stock minus backlog) plus all outstanding orders that will arrive within the shorter lead-time. The regular inventory position includes the net inventory and all outstanding orders. The dual index policy operates by placing orders with the emergency and regular supplier respectively to raise inventory positions to their base-stock levels.

In this paper we propose a natural extension of the dual-index policy to a two-echelon periodic review inventory system with two supply modes at the most upstream stock point. We consider the minimization of inventory holding, backlogging and both per unit and fixed emergency ordering costs.

We provide nested newboy characterizations for two of the three basestock levels involved and show a separability result for the difference with the remaining base-stock level. We use results for the single-echelon system to efficiently approximate the distributions of random variables involved in the news-boy equations and find an asymptotically correct approximation for both the per unit and fixed emergency ordering costs. Based on these results we provide an algorithm for setting base-stock levels in a computationally efficient manner. In a numerical study we investigate the accuracy of these approximations.

Keywords: Dual sourcing, Multiechelon, Markov chains, Inventory control, Lead times

Transportation delays in reverse logistics

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In this paper we extend MRP theory in reverse logistics including substantial transportation time delays. Our aim is to demonstrate the versatility obtained from combining input-output analysis and Laplace transforms enabling an analysis of a supply chain including four sub-systems, namely manufacturing, distribution, consumption and reverse logistics, when distances between activity cells and time lags between two activity cells play important roles. However, here we will concentrate our analysis on the reverse logistics (recycling, remanufacturing) closing the loop of the global supply chain. We intend to show that such a system may accurately be described using input and output matrices collected together in a corresponding matrix for the system as a whole. Activity levels, governing the speed of the respective processes at different locations, in general, will be considered as decision variables. We will use the Net Present Value as a measure of this performance.

Determining a supplier's discount schedule for a family of items

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The question of a quantity discount has usually been analyzed from the perspective of the buyer: For a given discount scheme, should that buyer purchase a large enough amount, to be able to take advantage of a reduced cost per unit? Here we develop a model to aid a supplier in setting the quantity discount policy.

Consider a family of SKUs with constant, deterministic demand, for which the supplier will offer a quantity discount to a single buyer. That discount will be set according to the aggregate purchases of the product group; management of those items is according to the modified periodic policy (MPP). We define what is meant by the optimal discount scheme, and show how to determine it.

In the MPP, one or more SKUs are considered "base items", replenished every T periods; all other SKUs in the group are replenished less often, at an order quantity that will last some multiple of T periods. With the group discount, a buyer's best decision could be to order a larger amount, one that will satisfy demand during a longer interval (a greater multiple of the base period T). However, that interval between replenishments (i.e. the quantity break point for the group discount) is chosen by maximizing the supplier's payoff function. The supplier offers that discount, to encourage the buyer to take it, by providing a positive payoff to her.

In terms of the particular replenishment intervals involved, we determine an upper bound and also a lower bound on the percentage of discount the supplier should offer. We demonstrate that, for any discount percentage between the two bounds, both the supplier and the buyer will benefit from the group discount policy. These conditions will be satisfied for a range of parameter values which we will identify.

Keywords: Quantity discount, Modified periodic policy, Supplier's point of view

AS/RS single command and dual command travel time analytical model for 3 class-based storage allocation

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Multi-shuttle Automated Storage and Retrieval Systems (AS/RS) are quite used in high performance intensive warehouses. The adopted storage allocation policies are mainly two: random and class based. The first storage policy is widely studied and developed in the literature while the class based storage policy still shows some lacks and gaps.This paper presents an analytical model for the computation of travel time for automated warehouses with multi-shuttle AS/RS with a class based storage and multi-command cycles. Aim of this work is the calculation of the mean travel time for the single, dual, and quadruple command cycles in the configuration with the input/output located in the bottom/left corner of the warehouse varying the Pareto ABC curve.

Acceleration/deceleration are neglected. A simulation model of the multi-shuttle AS/RS has been developed accordingly with a multi scenario approach to validate the performance of the proposed analytical travel time models under different configurations of the system (shape and dimension of the classes, Pareto ABC curve). Obtained results are presented and discussed by the illustration of a numerical example and an experimental analysis.

Keywords: Multi-shuttle AS/RS, Class based storage, Travel time model, Simulation

Non-cooperative consignment stock strategies for management in supply chain

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A deterministic model in which a vendor produces a product and supplies it to the buyer is considered. The final product is distributed by shipping it in discrete lots from the vendor's stock to buyer's stock (realized instantaneously). In the case of central coordination, the problem is to find a schedule which minimizes the average total (production, shipping, replenishment and holding) common cost for a given (or infinite) time horizon. We investigate a case without central coordination. In the competitive situation, the objective is to determine a schedule (a production – distribution cycle) which minimizes the individual average total cost. The idea of optimization allows (for isolated situations) the vendor to calculate the Economic Production Quantity (EPQ), although it might be significantly different from the buyer's EOQ. The application of consignment stock (CS) policies leads to the suppression of the vendor inventory by use the buyer's warehouse to stock the product. For CS policies we assume that the production batch is partitioned as $Q = kq^v + nq^b$. The four decisions to make are: the individual equal in size delivered amounts q^v, the number *k* of non delayed vendor's deliveries, and the number *n* - how many deliveries can be delayed. Additionally, we consider the case that the buyer receives the delayed deliveries just to run out of the stock. Braglia and Zavanella (2003) and Zanoni and Grubbstrom (2004) incorporated CS policies in which sizes of all successive shipments from the vendor to the buyer within a production cycle are equal in size (the case $q^v = q^b$ - policies (q^v, q^b), where it is possible q^v, can be viewed from competition perspective – as non-cooperative individual strategies. A class of non-cooperative constrained games, indexed by two parameters (k,n) connected with partitions of shipment costs, is introduced. In each game, the vendor and buyer independently choose strategies to minimize their costs. The games differ in competitive regime – in classes of admissible policies. The existence of Nash equilibrium strategies is proved. Some properties and explicit formulas for equilibrium strategies are given.

Keywords: Supply chain, Inventory control, Consignment stock, Constrained games, Nash equilibrium

Optimal pricing policy of a deteriorating product by dynamic tracking control

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We study the optimal selling price of a deteriorating product in both cases of finite time horizon 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, we 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). For the case of infinite time horizon, an optimal pricing policy is derived through a similar solution approach when the initial inventory level meets some given conditions. Computational results are reported, to illustrate the effectiveness of the control policies developed.

Finite horizon stochastic inventory problem with two procurement modes: Near-myopic bounds

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In the supply chain context, the competition between suppliers is becoming, nowadays, rougher due to the globalization. Therefore, the gap between the corresponding procurement costs becomes more and more important essentially due to raw materials and workforce costs difference between the production sites. We model, in this paper, this difference between procurement costs by the possibility of ordering at each period, of a multi-period finite planning horizon, twice: the first order using a fast procurement mode with immediate delivery, and the second order using a slow procurement mode with one period delivery lead time. We assume that the slow procurement mode is less expensive and then more attractive. We develop a discounted backlog model, with proportional procurement, inventory holding and penalty shortage costs which are period dependent. The demand distributions are independent and non-stationary. Since the use of the traditional optimization techniques does not allow one to get a simple optimal analytical solution for such problems, we use the methodology developed by (Morton and Pentico, 1995) in order to provide upper and lower bounds on the optimal solution of our model. Firstly, we perform a cost transformation for the fast procurement mode, and then we provide an upper bound on the optimal required inventory level at the beginning of each period. We assume that the demand of each period is satisfied exclusively with units ordered at the previous period using the slow mode. The last assumption is proved, numerically, to be optimal in the case where a reasonable difference exists between the ordering costs of the slow and the fast modes. In this case, the fast procurement mode is used only to satisfy the backlogged orders from the previous period. This assumption permits us to provide an upper bound on the optimal quantity that must be ordered using the slow mode. Lower bounds on the optimal decision variables are also developed by the way of the same assumptions. Finally, we use the Near-Myopic heuristic given in (Morton and Pentico, 1995), which interpolates linearly between the stock-out probabilities induced by the upper and lower bounds. A numerical analysis is provided in order to compare the solution given by the bounds, provided in this paper, to the optimal solution given by dynamic stochastic programming.

Keywords: Inventory control, Procurement modes, Non-stationary demand, Near-myopic bounds, Approximate solution

Products return flows in inventory management: A general framework based on a supply chain simulator

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During the last decades, product return flows in inventory management have received growing attention and several quantitative models have been developed in order to face such complex issue. The objective of this paper is twofold. First the authors present a state of the art overview on the main inventory control models proposed (during the last decades) by researchers and scientists working in this specific area; in particular the authors aim at reviewing these models by considering the different modelling approaches for demand and return processes. Then an advanced modeling approach and a simulator for supporting supply chain design and management is presented. To this end a conceptual supply chain framework is proposed in order to create the base for developing a supply chain simulator. The supply chain simulator implementation is supported by verification techniques (i.e. debugging) to correctly translate in a computerized model the conceptual supply chain framework. A simulator validation is carried out first to set the proper length of the simulation runs and then to assess simulator accuracy in recreating a real supply chain. The simulator proposed in the paper is a decision making tool capable of analyzing different supply chain scenarios in terms of

- different inventory control policies (based on continuous review and inventory costs optimization);
- different behaviors of supply chain downstream actors (i.e. retailers or final markets) including stochastic rates of products returns with different levels of intensity and variability;
- different behaviors of supply chain upstream actors (i.e. distribution centers, manufacturers) including stochastic transportation lead time.

Supply chain behavior investigation both at local level (each supply chain node) and at global level (the whole supply chain) requires proper experimental design in order to consider not only the main effects of major factors but also their combined interactions. Experiments planning proposed in the paper is based on a soundness design that investigates how the major factors mentioned before (inventory control policies, upstream actors behaviors, etc.) affect multiple performance measures (at both local and global level) including fill rates, on hand inventories and inventory costs.Both the state of the art overview and the supply chain simulator have to be regarded as tools that can be used (for different scopes) by researchers as well as by supply chain managers. The review of different demand and return processes models provides the readers with a better understanding on what has been done so far in the area of supply chain inventory management with products returns. Supply chains are complex systems and require ad-hoc models to tackle problems and indentify optimal

solutions for inventory management as well as to support the decision process. To this end the supply chain simulator proposed in the paper has to be regarded as a decision making tool for supply chain scenarios investigation considering the impact of critical factors on multiple performance measures.

Aggregate constrained inventory systems with independent multi-product demand: Control practices and theoretical limitations

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In practice, inventory managers are often confronted with a need to consider a number of additional aggregate constraints in the management of their inventories. Usually, these aggregate constraints result from available workspace, workforce or maximum investment limitations. However, there are cases where these aggregate constraints result from the inventory strategies themselves that are implemented. We consider a single period, multiple independent items and stationary inventory problem, with the objective of minimizing total inventory cost of all items in the system. The inventory cost function may include one or several cost components such as holding cost, ordering cost, possible shortage costs (€/period/unit, €/unit or €/period) or other costs. The aggregate constraints may possibly be applied on one or more resources or even on some performance measures. In some cases when correct cost estimation is difficult to obtain, certain costs are translated into resource or performance measure constraints. The aggregate constrained inventory problems have been discussed in the literature and in several inventory contexts: newsvendor, basestock policy, rQ policy, sS policy, continuous review or periodical review, continuous demand or discrete demand. In this paper, we analyze some recent relevant references and investigate the considered versions of the problem, the proposed model formulations and the algorithmic approaches. We then investigate the limitations from a practical viewpoint of these models and point out some possible direction for future improvements.

Keywords: Multi-product, Inventory control, Aggregate constraints, Independent demand, Newsvendor, rQ policy, sS policy, Basestock policy, Non-linear optimization

The analysis of bullwhip effect in a Arrow-Karlin-type supply chain

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The aim of the paper is to investigate the bullwhip effect of supply chains. Control theoretic analysis of bullwhip effect is extensively analyzed in the literature with Laplace transform. This paper tries to examine the effect for an extended Arrow-Karlin model. A two-stage supply chain (supplier-manufacturer) is studied with linear-convex costs functional. It is assumed that both firms minimize the relevant costs. Two cases are examined: supplier and manufacturer minimize the relevant costs decentralized, and a centralized decision rule. The question is answered, how to decrease the bullwhip effect. Another question is how to distribute the gain in a centralized cooperation.

Keywords: Optimal control, Supply chain, Bullwhip effect

Advance demand information, capacity restrictions and customer prioritization

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We study a single-period model with several buyers. They all have the same supplier and operate their separate markets. We study the situation where the buyers can make pre-orders before they observe their real demand and then later upon observing the demand they can issue an additional order, to be fulfilled to the extent that the supplier has developed enough capacity. Pre-orders can be considered as advance demand information, when seen from the perspective of the Supplier. It also enables risk-sharing between the supplier and his buyers, because if this option is not available all risk is at the supplier. Therefore, in order to motivate the buyers to pre-order the pre-order unit price should probably be somewhat lower than the after-order unit price. In the case of several buyers where some of these have lower priorities, pre-ordering can also be a necessity for those low-prioritized buyers in order to secure that they will receive enough deliveries.

First we study a single buyer case, where we investigate the case where the supplier may update his demand assessment based on the pre-order information. In particular we investigate its impact on the order quantities. Then we study the case of two buyers, where one buyer H has high priority and the other, L, has low priority. Here we will quantity the conjecture made above, that buyer L needs to pre-order more than buyer H.

Single period inventory control & pricing with spectral measures of risk

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Inventory management and pricing decisions based on quantitative models often rely on maximizing expected revenues or profits, which refers to the concept of risk-neutrality of the decision maker. Although many useful insights in operational problems can be obtained by such an approach, it is well understood that incorporating attitudes toward risk is an important lever for building new theories in other fields such as economics and finance. The level of risk associated with an investment might be as important as the expected gain from the investment. Hence, it is necessary to find appropriate measures of risk and the appropriate objectives related to or including these risk measures for inventory control & pricing problems.

After the axiomatic foundation of coherent risk measures the application of risk measures to inventory models such as Conditional Value-at-risk (CVaR) or convex combinations of mean and CVaR became popular. In an early draft Chen et al. (2004) uses a CVaR objective and Jammernegg and Kischka (2007) propose a convex combination of high and low profits, while Chen et al. (2009) analyze the combined inventory & pricing problem under a CVaR objective. However, the different risk measures are special cases of the general class of spectral risk measures introduced by Acerbi (2002).

In our work we apply spectral risk measures to the inventory control & pricing problem and derive optimal policies and structural properties. By doing so we are able to unify the results obtained so far in the literature for the case of zero and non-zero shortage penalty cost. In particular, we show convexity results and structural properties for the inventory control and under some assumptions also for the joint inventory & pricing problem.

Keywords: Inventory control, Pricing, Risk aversion, Spectral risk measure

A savings-heuristic and lower bound for placing strategic safety stock in supply chains

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Placing safety stock in general supply chains is NP-hard inside the guaranteed service approach (GSA) framework. We cannot expect to find efficient exact methods for this problem unless P=NP. Because industrial instances are large and complex, it is important to study heuristics and lower bounds for the problem. We present an improvement heuristic and an associated lower bound for serial systems and discuss extensions to more complex networks. The heuristic starts with an initial solution where each location has safetystock to cover its processing time. Step-by-step, it merges coverage times of two stockpoints, removing all safetystock at the more upstream one. Stockpoints are chosen greedily. The cost reduction is computed locally and the heuristic's runtime is quadratic. It does not remove safetystock from a location that has safetystock in the optimal solution. Hence, a side-result is a set of solutions that contains the optimum, and might be much smaller than the complete search space.

The lower bound is based on two ideas. First, locations with safetystock decouple a chain into shorter sub chains. The optimum cannot have less total cost than the most "expensive" of the sub chains (after modification). Second, every processing time must be covered more downstream. We compute the minimal additional costs that the processing time will raise at any potential location. Both ideas are combined to give a lower bound on the optimal cost.

A numerical study evaluates the quality of the heuristic and the lower bound. The serial chain has up to 12 stockpoints, end-customer demand is normally distributed with small, medium and large means and coefficients of variation. Different holding cost functions are assumed. Alpha service levels vary between 0,5 and 0,99. In total, 24.300 instances are solved with a dynamic program, the proposed heuristic and we compute the lower bounds.

Despite its simplicity, the heuristic 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 (0,99). The structure of the optimum influences the quality of the lower bound. If it involves strong pooling effects or large sub chains, the lower bound is tighter than 10%, and larger in other cases. Further, we present the current state of extending the heuristic and the lower bound to convergent or general acyclic GSA systems.

Keywords: Safety stock, Quaranteed service approach, Lower bound, Heuristic

A comparison of metaheuristics for strategic safety stock allocation in supply chains

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Safety stock allocation inside the guaranteed service approach (GSA) can be done efficiently with dynamic programs if the supply chain is serial, divergent or convergent. The problem becomes NP-hard in general networks, so we cannot expect a discovery of efficient exact approaches unless P=NP. We present a numerical study of reliability and runtime of several black-box metaheuristics for safety stock allocation. Some results are explained on the basis of decomposition theory for Evolutionary Algorithms. We use a 1+1 Evolutionary Algorithm, a simple Genetic Algorithm (SGA) and a Bayesian Optimization Algorithm (BOA). The 1+1 EA is a simple stochastic hillclimber. SGA uses one-point crossover and bit-flipping mutation. BOA tries to discover and learn the structure of good safety stock allocations by constructing a Bayesian network of dependencies between coverage times. The Bayesian network encodes the probability of holding safety stock in a superior solution at a location. Adaptation of the three methods is kept to the minimum. Their representation maps the coverage decisions onto a string of binary variables. Besides evaluating safety stock allocations, they are not adapted further. We do not modify search operators, starting solutions or other elements of the heuristics. GSA instances are randomly generated and of the serial, divergent, convergent, and general network type with up to 105 stockpoints. The 1+1 EA is fast, but delivers reliable results only for serial networks. The SGA solves serial and divergent instances reliably. The BOA routinely solves instances of all network types to global optimality. It has the largest running times because it is constantly learning a Bayesian network. We show that GSA instances are decomposable in the sense of Genetic Algorithms and use this result to explain why metaheuristics like the BOA might be specifically suited to solving them. Our results justify a broad investigation of metaheuristics' performance in safety stock allocation. Specifically for general acyclic networks the application of metaheuristics appears promising. Our study yields good results even without much problem-specific adaptation. We expect that the results can be surpassed by problem-specific metaheuristics and discuss ways to obtain such adapted methods. Further, we present the current state in applying the heuristics to existing real-world benchmark instances.

Keywords: Safety stock, Metaheuristics, Local search, Machine learning, Guaranteed service approach

A simple closed economic system subject to disruptions analysed in terms of MRP theory

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In the last few years, MRP theory has been extended to more general types of material flow systems than of the assembly type from which it originally was developed. This theory describes in a compact way the flows and accumulation of goods in an economic system where delays and other types of timing considerations are important features for their development over time. On the one hand, matrices from Input-Output Analysis are used for capturing the technical relationships of the transformation of goods and services in the value chain, on the other, 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 enable stochastic properties to be efficiently handled, as well as economic consequences to be determined by means of a Net Present Value analysis.

In this paper we attempt to build a model of a simplest possible closed economic system applying MRP Theory. Our aim is to portray the most basic equilibrium properties of the system under the assumption of a steady growth, and how the system may disrupt due to unforeseen events. We will focus our attention on how items of capital tied up in inventories, production and domestic assets, risk, and protection against disruptions can be modelled in terms of MRP Theory.

A Lagrangean approach to dynamic lotsizing

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The *lotsizing problem* is probably the most celebrated issue in the production-economic literature, ever since the days of Ford Whitman Harris, who presented his first EOQ formula in 1913. The *dynamic lotsizing problem* generalises this issue to determine batch quantities when required amounts vary over time. Previously has been demonstrated that *inner-corner conditions* for an optimum production plan in continuous time reduce the number of possible replenishment times to a finite set of given points at which either a replenishment is made, or not. The problem is thus turned into choosing from a set of zero/one decisions with 2^{n-1} alternatives, of which at least one solution must be optimal, where n is the number of requirement events. This binary representation of the problem led to the development of the *Triple Algorithm*, which is of the forward type and is applicable either an Average Cost approach or the Net Present Value principle is applied, and it performs in continuous as well as in discrete time. The two most well-known methods for solving the dynamic lotsizing problem are the *Wagner-Whitin* dynamic programming algorithm, published by Harvey M. Wagner and Thomson M. Whitin in 1958, which leads to an optimal solution, and the Silver-Meal heuristic (1973), which leads to a near-optimal solution. Also a few other discrete-time algorithms have been presented later, such as by Federgruen and Tzur (1991). It has been shown previously that W-W as well as the Silver-Meal heuristic may be stated both in discrete and continuous time, either the *Net Present Value* (NPV) or the *Average Cost* (AC) is applied as the objective function. In this paper we formulate the dynamic lotsizing problem analytically using the binary representation mentioned. A Lagrangean function for each of the two objective functions is stated and the necessary Kuhn-Tucker conditions for an optimum derived. This study analyses properties of the fundamental inequalities of the optimisation conditions. It is also shown that the Kuhn-Tucker conditions will not always generate a unique optimum.

Keywords: Dynamic lotsizing, Net present value, EOQ, Lagrangean approach, Triple algorithm

Analysis of a two-echelon supply chain with disruptions in supply

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In this talk we present models and analytical findings for a supply chain which consists of a central warehouse and two retailers, under the condition that there is uncertainty regarding the stock replenishments. In the system that we analyze, the central warehouse has the opportunity to replenish the system-wide stock at the beginning of each planning period. Then, the central warehouse makes a decision as to how much stock to allocate to each retailer. After stock allocation, customer (deterministic) demands are observed at the retailers, and costs are incurred at each location.

This framework is well known and commonly considered in supply chain/multi-echelon inventory literature. Our study differs from previous work in two respects: (1) the central warehouse may not be able to realize a stock replenishment due to supply disruption, (2) the demands observed at the retailers are deterministic (but possibly non-stationary) reflecting long-term commitments of the retailers. Our aim in this work is to come up with efficient policies that aim to minimize system-wide costs over a finite planning horizon. Under a particular rule for allocating available stock at the warehouse among retailers (which favors the retailer with larger backorder cost), we are able to show that (1) the optimal replenishment policy is to raise the system-wide inventory up to a level, and (2) this level can be characterized as cumulative system-wide demand for a number of periods. We also provide an algorithm which can compute these order-up-to levels in an efficient manner.

Keywords: Supply chain, Multi-echelon inventory, Supply uncertainty

Vendor-managed inventory for multiple customers under time-varying demand

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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. In this paper, we study these supply chain practices for a vendor and multiple customers who face time-varying, but deterministic, external demand for a single product. Our aim is to select the right set of customers for a vendor under VMI and C&VMI. We develop integer programming models when VMI and C&VMI are alternative options to the traditional way of doing business where a customer initiates orders. We 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 examples were used to compare and contrast the optimal solutions in traditional way of doing business, VMI, and C&VMI. The number of supply-chain customers in those examples varied from one to 16. 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 customers increase, number of VMI agreements also increase, but there will always be at most eight C&VMI agreements. Most of the vendor's savings in either partnership result from efficiencies in transportation. We conclude 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.

Keywords: Supply chain, Vendor managed inventory, Direct replenishment, Logistics

Inventory systems with variable capacity

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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, we consider that supplier capacity is 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, we consider that the yield of the item is 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. We extend a model with variable supplier capacity in several directions and analyze the effects of variable supplier capacity. First, we investigate a lot-sizing problem in an EOQ model with variable supplier capacity and random yield. Second, we develop an EOQ model with storage or investment constraints when multiple items are considered. Third, we apply a distribution-free approach (DFA) 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.

Computing an optimal ordering policy and deriving a day dependent (s, S) rule for perishables in the presence of fixed ordering costs

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Objectives of study: For a product with a fixed shelf life, we compute a cost optimal stock-age dependent ordering policy, assuming fixed ordering costs and unit outdating, shortage and holding costs. The motivation for this problem comes from a case study in managing inventories of blood platelet concentrates (BPCs) with a shelf life of 3 to 7 days. Blood banks deliver BPCs to hospitals more or less on demand, resulting in high inefficiencies in the distribution. We improve the efficiency by deriving a cost optimal ordering policy for hospitals taking into account the fixed costs related to ordering, i.e. the distribution costs.

Materials and Methods: We present an SDP-Simulation approach that combines the strengths of Stochastic dynamic programming (SDP) and Simulation. A cost-optimal policy is computed by solving a periodic Markov decision problem (MDP). Demand is stochastic and periodic. Any shortages are modeled as lost sales. Orders are placed on Monday to Friday only and depend on the stock volume of each age category. This makes the MDP high-dimensional and it requires aggregation to solve large scale problems. By simulation of the optimal policy we create frequency tables from which we derive simpler rules, such as a day dependent (*s*, *S*) rule. This rule is tested by simulation against the optimal policy and other simple rules.

Results: The SDP-Simulation approach generates an optimal policy and deducts simpler rules from it. The derivation of the optimal ordering policy as a benchmark for simple rules seems to be a contribution to the literature on its own. Further the approach generates estimates of optimal parameter values of common ordering policies. For the Dutch case on distributing BPCs to hospitals it is demonstrated that one can significantly save on the ordering costs (i.e. distribution costs) with only a slight effect on the outdating and the occurrence of shortages.

Conclusions: The generic SDP-Simulation approach seems to be the first approach reported in literature that computes an optimal stock-age dependent ordering policy under fixed ordering costs. As such it provides a benchmark to assess any simpler rules, which may be generated by the SDP-Simulation approach too. The approach is applicable in other settings where fixed ordering costs apply.

Keywords: Perishable inventory, Dynamic programming, Simulation, (s,S) rules

Evaluation of stock allocation policies in a divergent inventory system with shipment consolidation

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In this paper we consider a one-warehouse N-retailer inventory system characterized by access to real-time point-of-sale data, and a time based dispatching and shipment consolidation policy at the warehouse. More precisely, inventory is reviewed continuously, while a consolidated shipment (for example, a truck) to all retailers is dispatched from the warehouse at regular time intervals. The focus is on investigating the cost benefits of using state-dependent myopic allocation policies instead of a simple FCFS (First-Come-First-Serve) rule to allocate shipped goods to the retailers. The analysis aims to shed some light on when, if ever, FCFS is a reasonable policy to use in this type of system? The FCFS allocations of items to retailers are determined by the sequence in which retailer orders (or equivalently customer demands) arrive to the warehouse. Applying the myopic policies enables the warehouse to postpone the allocation decision to the moment of shipment (from the warehouse) or the moments of delivery (to the different retailers), and to base it on the inventory information available at those times. A 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.

Keywords: Inventory, Stock allocation, Shipment consolidation, Multi-echelon, Stochastic, Continuous review

Optimal production lots for items with imperfect production processes using simple computing method

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Research on imperfect quality production process has drawn attentions of the academia and practitioners over decades. While most studies apply the traditional optimization techniques, this study considers an alternative approach to develop an inventory model for imperfect production process, using simple and analytical computing method. Recently, methods without using calculus have grown prevalent. In the existing literature, there are three methods using no derivatives, which are: (i) complete square method, (ii) cost difference comparisons, and (iii) arithmetic-geometric-mean-inequality method. By using the above methods, most students who are unfamiliar with calculus may be able to easily understand the solution procedures for inventory problems. Sensitivity analysis is essential in deriving insights from decision-support models in a wide range of applications. Koltai and Terlaky (2000) showed that managerial questions were not answered satisfactorily with the mathematical interpretation of the sensitivity analysis. Singh et al. (2005) studied multi-parametric sensitivity analysis of programming problems with linear-plus-linear fractional objective function using the concept of maximum volume in the tolerance region. Borgonovo (2010) defined sensitivity measures that do not rest on differentiability and are not related to classical differentiability with comparative statics indicators, then demonstrated the result which allows us to obtain sensitivity measures at the same cost of one-variable-at-a-time methods; it makes their estimation feasible, even for computationally intensive models. Sensitivity analysis has mostly been based on discrete values of parameter, while continuous values received little attention. This study develops an inventory model for imperfect production processes to obtain the economic production quantity without using derivatives, and the analytical method for sensitivity analysis is used.

Perishable inventory problem with a bundle

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We consider the bundle sale for perishable inventory, and seek 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. That is, we consider the following perishable inventory problem.(1) A periodic review inventory model is considered for one planning period and perishable product. The period length is arbitrary but fixed.(2) Ordering takes place at the start of a period with unit purchasing *c*,(3) Maximum lifetime of the perishable commodity treated is 2 periods. If the commodity has not been depleted by demand until the period it reaches age 2, then it perishes and must be discarded with unit outdating cost θ.(4) Unit holding cost *h,* unit shortage cost *p*, unit selling prices for the commodity with remaining life time 2 and 1 are r_1 ,r_2 ($r_1 < r_2$) respectively, and further bundle sale price *r* such that $r \le r_1+r_2$ is introduced.(5) Customers select basically new one but if only old one is left, they accept to buythem. That is LIFO (Last in First out) issuing policy is adopted. However with some percentage *g(r)* of customers buy the bundle set consisting of both remaining life 1 and 2 commodities if both are available. We assume that *g(r)* is non-increasing function of *r* such that $g(r_1+r_2)=0$, $g(r_2)=1$. (6) Demand quantities in successive periods are independent and identically distributed non-negative random variables with the distribution function $F(\cdot)$ with density function $f(\cdot)$, that is continuous with the expection $F(0)= f(0)=0$

(7) Under the above setting, we seek an optimal ordering quantity *y** and optimal bundle price *r** to maximize the expected profit function of the planning period. First we derive each expected sales quantities, that is, sales quantity of the commodityof remaining life time 2(fresh one), that of remaining life time 1(old one) and that of the bundle sale. Further we derive expected shortage quantity, that of holding quantity and that of outdating quantity. Then we can derive an expected profit function with respect to *y* and *r* and some properties of an optimal solution (*y**, *r**) to maximize the expected profit function. Finally we summarize the results and discuss further research problems.

Keywords: Perishable item, LIFO issuing policy, Bundle, Optimal ordering quantity, Optimal bundle price

Risk preferences of a newsvendor with service and loss constraints

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Experimental findings state that the actual order quantity deviates from the optimal quantity prescribed by the newsvendor model maximising the expected profit. Moreover empirical observations show that managers tend to order less than the classical newsvendor because they base their decisions on other performance measures. From the perspective of supply chain management an inventory manager should control not only internal-facing performance measures like expected profit and the probability of loss but also customer-related measures like the level of product availability.

Using the newsvendor framework, we present an approach to determine an order quantity which is more relevant for the observed ordering behaviour of an inventory manager. For that, we first derive the set of admissible order quantities for a service constraint – a lower bound for the cycle service level - and for a loss constraint specified by an upper bound for the probability of loss. Using the optimal order quantity derived from a newsvendor model with a mean-deviation rule as objective function (risk is measured by the conditional value at risk) we analyze the implication of the relations of the profit value of the product and the prescribed performance measures. For given risk preferences we present conditions which imply that the optimal admissible solution is a corner solution.

On the other hand we derive implications from the prescribed service and loss constraints for the risk preference of the decision maker. Assuming that the optimal unrestricted solution is an admissible order quantity one can characterize the risk preference of the newsvendor. If the cycle service level is larger than the profit value, all admissible order quantities are larger than the optimal order quantity of the classical newsvendor, i.e. the decision maker in any case exploits risk-taking behaviour. This is true independently of the demand distribution provided an admissible solution exists. Contrary, if the cycle service level is smaller than the profit value, the newsvendor is a risk-averter for small order quantities. In this situation, the higher the probability of loss is, the more likely the newsvendor will be a risk-taker for high order quantities. This result depends crucially on the demand distribution. Based on these insights the decision maker then can choose an order quantity by comparing the resulting values of performance measures like expected profit, expected loss and fill rate.

Continuous-review, lost-sales inventory models with Poisson demand, a fixed lead time and no fixed order cost

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We reconsider the lost-sales inventory system studied by Hill in a paper published in EJOR (2007). That paper considers policies which make use of the observation that, for lost-sales models, base-stock policies can be improved by imposing a delay between the placement of successive orders. The paper compares the best pure base-stock policy, for which the base stock is denoted S_m, with two modified base-stock policies having a lower bound on the delays (LB) and delays updated every time a sale occurs (UD), respectively. The specification of the UD policy is complex because the delay has to be computed every time a sale occurs. Hill therefore admits that the UD policy is "less likely to be operationally acceptable". He does not mention that his LB policy can be substantially improved by specifying the lower bound differently. In a paper published in IJPE (2001) we have suggested to specify the lower bound on the delays as the ratio, denoted t_m, of the lead time and S_m. Using the same test bed as Hill, we investigate three LB policies by simulation in our numericalstudy. The first is the (S_m,t_m) policy. The second, denoted $(S_m,t^*[S_m])$, is the best LB policy with base stock S_m. The third is the best LB policy, which is denoted $(S^*,t^*[S^*])$. These policies perform better than the UD policy in all 19 settings where the latter policy reduces the long-run average cost per unit time of the $(S_m,0)$ policy by at least 1%. In most of the 19 settings the relative cost reduction of the (S_m,t_m) policy, which is easy to compute, is much larger than the relative cost reduction of the UD policy. The $(S_m,t^*[S_m])$ and $(S^*,t^*[S^*])$ policies provide additional relative cost reductions. The largest relative reductions are obtained in the case where the lead time is 16 (the time unit is one divided by the demand rate) and the lost sales cost per unit is 4 (the monetary unit is the unitholding cost per unit time). For that case, Hill reports that $S_m=11$ and that the cost reductions are 0.45% and 3.32% for his LB policy and the UD policy, respectively. We find that the cost reductions are 9.85% for the $(S_m=11,t_m=1.45)$ policy, 10.22% for the $(S_m=11,t^*[S_m]=1.58)$ policy and 12.30% for the $(S^*=14,t^*[S^*]=1.54)$ policy.

Keywords: Continuous review, Lost sales, Base stock, Simple policy, Simulation

A collaborative strategy for deteriorating inventory system with imperfect items and supplier credits

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In this study, we 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 affected the percentage of the extra total profit.

Keywords: Inventory, Imperfect items, Trade credit, Deterioration, Price-sensitive demand

Coordinating production and inventory control in a whole green manufacturing supply chain network

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This paper proposes how to coordinate production and inventory control in a whole green manufacturing supply chain network which consists of multiple-raw materials suppliers named as tier-2 suppliers, multiple parts suppliers named as tier-1 suppliers, a manufacturer, multiple distributors, multiple retailers and a third party collector for used finished products. In this system, tier-2 suppliers supply raw materials to tier-1 suppliers producing parts. Parts are then supplied to a manufacturer which manufactures and assembles parts into finished products. Then, the finished products will be delivered to distributors distributing them to retailers. A Third party will collect the used finished products from end customers and dissemble them into parts. The good quality used parts will be returned to the system to be manufactured and assembled again into the finished products. To manage how many items will be ordered and produced by each player in the supply chain, coordination is needed among players in order to minimize the total annual associated costs. As there are many suppliers which have the opportunity to be part of the system, there is a selection process for the suppliers. The problem model considers some constraints of the players in the system, such as limited contract period, capacity and delivery. The model is stated as the optimization problem which is solved by a mixed integer non-linear programming method. The decision variables of this model are replenishment cycle time for each player, production and order quantity per cycle for each type of items, etc. The objective function is the whole system's annual total associated cost. The model and solution method is illustrated on an example problem.

Keywords: Green manufacturing supply chain, Production, Inventory, Coordination, Constraint

A Greedy Algorithm for a multiple sourcing - Multiple plant supply chain model

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Supply chain models take a primary hand in mapping and solving real problems, arise in the production, concerning with the maximization of the expected profits. Each model takes into consideration a set of associated parameters to find or not an optimum feasible set of solutions.

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.

The paper is completed with a detailed small numerical example. Computational results by sets of various data are also presented.

Approaches to inventory management in supply chains: A comparative study

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Various studies on global economical trends emphasize that supply chains, rather than individual enterprises compete with each other on the global market. Still, most of the research on inventory models focuses on centralized decision models for individual companies. Extension of these results to supply chains receives growing attention only in the past years.

In this study we present and compare four different approaches to inventory management in supply chains:

- the decomposition approach, where each company optimizes its own production and inventories without considering how this affects its partners' situation
- the integrated approach, which assumes complete trust between the partners who minimize the total production and logistic cost throughout the supply chain
- the coordination approach, in which self-interested autonomous partners adopt some coordination mechanism to mutually benefit from the decrease of costs in the supply chain; and finally
- the bilevel approach, where the partner who decides first predicts and takes into account the response that it can expect from its self-interested partners

Each of these approaches will be illustrated on a simple two-level single-item lot sizing problem.

In the study we analyze the assumptions made by each of the approaches about the cooperation between the partners, especially regarding the information sharing aspects and the contractual requirements. The potential consequences of violating the assumptions will also be investigated. Computational tractability and extensibility to multiple partners or levels in the supply chain will also be considered. Finally, we compare the implied cost, both for the supply chain and for the individual partners, by theoretical considerations and by numerical experiments on the sample problem.

Keywords: Inventory management, Supply chain, Decomposition, Coordination, Bilevel optimization

Inventory control for perishable items with correlated demand

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In food retailing, the limited shelf-life of products requires tailored inventory control policies and the problem turns out to be complex as simple base-stock-policies are no longer optimal. In a recent paper, Minner and Transchel (2010) proposed a dynamic order quantity determination method for a perishable product under non-stationary random demand to satisfy required service level constraints. However, it was assumed demands in consecutive periods are uncorrelated. Empirical evidence, however, shows that customer sales exhibit significant serial correlation. In this paper we present an extension of the proposed method to account for this effect. The item under consideration is perishable with a deterministic shelf-life. Inventory is reviewed periodically and replenished items arrive after a deterministic lead time of L periods. Demand is assumed to follow a discrete distribution and excessive demands are lost. Demand over time is serially correlated according to a (discrete) ARMA(p,q) process. We derive expressions for the inventory level when the order to be placed arrives under both FIFO and LIFO issuing policies. Based on this, the order quantity that achieves a marginal service level (either non-stockout probability or fill-rate) is determined. In a simulation study we illustrate the impact of different types of demand correlation on the required inventory levels and how available findings for durable products under correlated demand change depending on the shelf-life of a product.

Keywords: Perishable products, Correlated demand, Service level constraint

Coordinated inventory policy considering freight consolidation in a supply chain

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In recent years, manufacturers have sought inventory strategies that reduce costs as well as maintain high levels of service because they face increasing challenges to produce quality products at competitive prices and within shortened lead times. Therefore, they are working to develop new production management techniques such as just in time (JIT) and optimized production technology (OPT) that emphasize ordering small amounts of inventory. The manufacturers are motivated to change their strategies for managing inventory and logistics; this leads them to devise strategies compatible with substantial reductions or even elimination of their stocks of inventory. This is generally accomplished with smaller and more frequent shipments, resulting in a lower likelihood of full-cargo capacity. However, these strategies sometimes result in a higher total cost. Therefore, we need to consider the consolidation of a customer's order over time. Order consolidation has been practiced by many firms for a number of years as an effective method to reduce transportation costs. It has also been the subject of recent interest as a means to cope with the widening spread between truckload and less-than-truckload rates. We develop mathematical models for coordinated inventory and transportation decisions for a special type of supply chain, namely, a three-level supply chain comprising a manufacturer, warehouse, and customer. In addition, three inventory policies are considered. Under an immediate delivery policy, an outbound shipment is released each time a demand is realized. On the other hand, if these shipments are consolidated over time, then more economical outbound freight quantities can be dispatched. The model presented in this study describes the minimization of the coordinated total relevant cost. Further, we apply the existing sharing technique for benefits and losses in two-level supply chains to our three-level model. Finally, we derive the optimal solution procedural steps for the developed model and study the effects of the compensation policy on the optimal results with the help of numerical examples.

Simple evaluation of (R,Q) policies for inventory systems with continuous review and perishable items

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Objectives of study: We consider a classical single echelon inventory system where items have fixed lifetimes. The single-echelon inventory system consists of a single location which is controlled by a continuous review (R,Q) policy. In our model we consider backorder costs per unit, but also backorder costs per unit and unit time. A paper by Chiu (1995) presents a technique for approximate evaluation of the same system as we consider (backorder costs per unit). One of our aims is to develop a new approach for modeling a batch-ordering system in the case of finite lifetimes of items. Hence, when backorders are allowed in our model, we will compare our results to those obtained by Chiu (1995).Many companies today are controlling their inventories by assuming infinite lifetime of products, which may lead to quite large cost increases. This could be the case since when dealing with perishable products large inventories may lead to very high costs due to perishability, while too small inventories may cause poor customer service (or equivalently high penalty costs). Moreover, since the expiration of products is not taken into account in infinite lifetime models, calculated inventory levels may be quite inaccurate. Hence, there is a pressing need for more sophisticated ways to manage perishable goods in supply chains.

Materials and methods: The method used to solve our problem is classical stochastic inventory modeling. The solution procedure is mainly based on the steady state behavior of the base-stock policy.

Results: The results from the numerical evaluation of our heuristic solution procedure indicate that our methods work well. It turns out that our approach gives significantly better results than those obtained by Chiu (1995).

Conclusions: We have developed a method for evaluating (R,Q) policies in inventory systems with perishable items. Our method is simple and performs significantly better than other existing solution procedures.

Keywords: Inventory control, Perishable items, Stochastic demand, Fixed lifetimes, Batch ordering policies

A literature review about Kanban and Conwip

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A literature review has been done late 2009 about pull based production systems, especially Kanban and Conwip. ISI Web of Knowledge and Scopus have been used as search engines. The objective of the literature review was to present a base for a study and to seek answers to a lot of questions:

A literature review has been done late 2009 about pull based production systems, especially Kanban and Conwip. ISI Web of Knowledge and Scopus have been used as search engines. The objective of the literature review was to present a base for a study and to seek answers to a lot of questions:

What is the difference in different performances between Kanban and Conwip? Which performance measures are used in previous and current research regarding pull based production systems? How are pull based production systems controlled to achieve special performances? To achieve a special performance when using Kanban; where, in which station, to increase or decrease the number of kanbans? Has the research of pull based systems changed its focus over time?

Other interests with this literature review have been to find the different peoples that work in this area and how they are working. Which articles are most sited? Who are the most contributing authors? And in what journals are the research published?

Number of found articles

Search Criteria	ISI	Scopus
Kanban	476	750
CONWIP	117	144

Keywords: Kanban, Conwip, Pull based production systems, Performance measurements

Single buyer, multiple supplier coordination with shipping frequencies

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There exist several advantages for having a supply base with multiple parties. Other than frequently stated risk and economies of scale arguments, we 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, we develop a method that simultaneously determines supplier choice, supply allocation, and the ordering policies between the buyer and the suppliers. We extend existing approaches 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 we assume an integer number of times a supplier can ship available items in an overall replenishment cycle. We 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.

Keywords: Multiple suppliers, Supplier coordination, Economic production quantity, Non-linear optimization

Optimal policies for a dynamic inventory model

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Probabilistic inventory models of multi-period have been studied in order to get optimal policies. The inventory model investigated in this presentation is a generalized news vendor problem. Our main purpose in this paper is to establish a method of getting an economic order quantity and the effect of changing demand on the inventory management is also studied. Our decision criterion is the minimization of the expected total cost which includes the purchasing, holding, and shortage costs without setup cost. Let $f_n^i(x)$ be the sum of the expected total cost from period *i* through period *i+n-1* provided an optimal policy is done at each opportunity. The expectation of the total inventory cost at *i*-th period is denoted by $E^i(z)$ and phi(*b*) is the probabilistic density function of the demand distribution at period *i*. Let $g_{n-1}^{i+1}(z)$ be the function that is obtained by integrating the function $f_{n-1}^{i+1}(z-b)\text{phi}(b)$ from 0 to infinity with respect to the variable *b*. It follows from the fundamental law of the dynamic programming that

$f_n^i(x)=min_{z>=x}\{ E^i(z)+a\ lpha\ g_{n-1}^{i+1}(z)\}$ where alpha is a discount factor. An optimal policy could be obtained by analyzing the functions $E^i(z)+a\ lpha\ g_{n-1}^{i+1}(z)$. The models of multi-period with varying demand are set by varying a parameter of demand distribution in each period.

A simple algorithm is presented in the case demand is decreasing period by period. Although a theoretical economic order quantity is proved to exist in general, it is too complicated to formulate a simple method. The optimal policies are shown in the model with a few periods. An economic order quantities in the models with a few periods are shown, which are computed by making use of the computer software Mathematica.

Evaluation of shipment size distributions in divergent Inventory systems with time based dispatching

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Our research concerns a multi-echelon inventory system consisting of one warehouse and multiple non-identical retailers. The system is characterized by a time-based dispatching and shipment consolidation policy at the warehouse, in conjunction with real-time point-of-sale data and centralized inventory information. This means that inventories are reviewed continuously, but shipments from the central warehouse are consolidated for groups of retailers and dispatched periodically. The time between shipments to a retailer group is referred to as the shipment interval. These intervals may be different for different retailer groups.

The focus of our work is to determine the shipment sizes associated with a choice of shipment intervals. The main contribution is that we derive the probability distribution of the shipment size to each retailer group, i.e., the amount of goods on each shipment. The approach we use is based on the idea to divide 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 we obtain the distribution of the total shipment size.

Our work builds on Marklund (2010), where the same type of system is analyzed but under the assumption that every planned shipment incurs the same fixed cost independent of the shipment size. For example, even if there are no units to ship, this model assumes the same fixed cost as if several trucks are needed. The main focus of this paper is the derivation of an exact method for evaluation of the inventory holding and backorder costs given a set of shipment intervals. Combining our results with this exact method for evaluation of the inventory holding and backorder costs, renders a more general model for joint evaluation of the cost impact of inventory and shipment decisions. Particularly, it allows the inclusion of transportation costs that increase stepwise with the quantity being shipped. It may also be used for analyzing the impact of joint transportation and inventory control decisions on CO2 emissions.

Keywords: Inventory, Multi-echelon, Shipment consolidation, Stochastic, Transportation

Optimal period replacement decisions for repairable products with pricing warranty cost

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Warranty is a guarantee in the form of a contract. Generally, it is provided by the manufacturer (seller) to customers for its products or services. The manufacturer (seller) has the responsibility to replace the part(s) or to restore the full function of the product provided it is under proper usage. Since the warranty policy can directly affect the manufacturing cost, the manufacturer has to take into consideration of the factors that can influence the customers' purchasing and also the reliability of the product during the policy making. Many different types of warranty policies for new products have been studied. Under free-repair warranty, when a failure occurs within a warranty period, manufacturer agrees to repair for the failure items free of charge. Yeh and Lo (1998) studied the effects of a free-repair warranty policy on the optimal production lot size and optimal burn-in time. Wang and Sheu (2003) considered a lot-size problem for products which are repairable and which are sold under a free-repair warranty policy. Yeo and Yuan (2009) investigated a system whose basic warranty coverage is minimal repair up to a specified warranty length. However, the warranty cost absorbed by the supplier will finally impute to the customers. Therefore, to evaluate the warranty cost is fairly important to both sides. The supplier has the responsibility to replace the part(s) of the product at each failure under warranty. To avoid too many failures, some suppliers support one or more replacements during warranty period. In this study, we develop an optimal replacement period by considering minimizing the expected warranty cost. Numerical example is provided to illustrate the theory.

Keywords: Warranty cost, Replacement, Repairable product

Joint pricing and inventory decisions under stockout-based substitution

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Product differentiation along key features is an important strategy for companies to target different customer needs and to increase market share. The organic market of groceries, for example, is growing at a steady pace of nearly 20 percent annually even though organic food is often twice as expensive as conventional food (Spindler 2007). The organic label is commonly used to differentiate products in the food market. However, product differentiation may also result in undesired sales cannibalization among products if prices and product availability are not properly aligned. Although being a very relevant issue in practice, jointly managing inventories and prices for multiple products taking product substitution into account has been sparsely addressed in the inventory management literature.

This paper examines a single-period joint inventory and pricing problem for partially substitutable products in a given assortment. We consider two vertically differentiated products, i.e., a high and a low quality product. Demand for both products is stochastic so that the retailer may stock out of one or both of them. If the high quality product is out-of-stock, customers do not substitute the low quality product and demand is lost. On the other hand, if the low quality product is out of stock, a certain portion of unsatisfied customers is willing to purchase the high quality product instead (if it is available) depending on its price. While the low quality product is a commodity with an exogenous price, the optimal price of the high quality product is determined endogenously. The retailer has to consider this price-dependent substitution effect in her price and inventory decision in addition to a possible overstocking and understocking. Two major research questions are addressed in this paper: 1) How do price management and stocking decisions interact given that demand and substitution rates are price-dependent?, 2) How does the optimal pricing and stocking policy perform in comparison to the use of a simple planning policy where both products are optimized independently? We present structural properties of the proposed model and provide managerial insights into the interaction of pricing, stocking decision, and product cannibalization under stockout-based substitution. Our approach is motivated by a large retail chain and verified using real industry data.

Keywords: Joint inventory and pricing decision, Newsvendor problem, Stockout-based substitution

Sensitivity of two-stage multi-product economic lotsizing models and their dependency on change-over and product cost ratios

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This study considers the production and inventory management problem of a two-stage production system. In case both production stages are physically connected it is obvious that materials are forced to flow. The economic lotsize depends on the holding cost of the end-product and the combined change-over cost of both production stages. On the other hand this 'flow shop' is forced to produce at the speed of the slowest stage. The benefit of this approach is the low amount of Work In Process inventory. When on the other hand, the involved stages are physically disconnected, a stock of intermediates acts as a decoupling point. Typically for the semi-process industry are high change-over costs for the process oriented first stage, which results in large lotsize differences for the different production stages. Using the stock of intermediates as a decoupling point avoids the complexity of synchronising operations but is an additional reason to augment the intermediate stock position. The disadvantage of this model is the high amount of Work-In-Process inventory. This paper proposes the 'synchronised planning model' realising a global optimum instead of the combination of two locally optimised settings.The mathematical model proves (for a two-stage single-product setting) that the optimal two-stage production frequency corresponds with the single EOQ solution for the first stage. In order to understand, within these lotsizing models, their dependency on product and change-over cost ratio's the economic production costs are compared for different settings of these cost parameters within both stages. Numerical examples prove that the conclusions about the optimal settings remain valid when extending the model to a two-stage multi-product setting. The research reveals 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 only be used when the end-product stage has a small added value and high change-over costs, compared to the first stage.The paper concludes with suggesting a practical common cycle approach to tackle a two-stage multi-product production and inventory management problem. The common cycle approach brings the benefit of a repetitive and predictable production schedule.

Keywords: Economical Lotsizing, Two stage production system, ELSP, Cyclical Production Scheduling

Simple heuristic approach for coordinating replenishments

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In this paper we present a simple uniform approach applicable to inventory problems involving coordination of replenishment. Examples for such inventory problems are the Joint Replenishment Problem (JRP), the One-depot Multi-Retailer Problem and the Economic Lot Scheduling Problem.

A cycle policy for the JRP e.g. prescribes replenishments at a constant interval of T periods where the individual items may either order once every mT periods with mÎN. Our procedure starts with ignoring all items but one, so basically we start with a one-product problem for which we want to find a basic period T and the replenishment frequency m_1 for item 1. The standard EOQ-formula gives the optimal T for this reduced problem with $m_1 = 1$. In the next steps we include one more item at the time and in every step i we determine a new optimal T and replenishment frequency m_i given the already fixed replenishment frequencies $m_1 \ldots m_{i-1}$. With including the last item the procedure has obtained a cycle policy with the optimal T given the frequencies $m_1 \ldots m_M$.

The same approach can be used for the One-depot Multi-retailer Problem where we start with a One-depot One-retailer Problem for which we can obtain an optimal solution. Adding one retailer at the time, the replenishment frequencies for the retailers are fixed sequentially. A similar approach is applicable for the Economic Lot Scheduling Problem. The procedure is highly suitable for implementation in a spreadsheet. The number of required calculations is about the same as solving M times an EOQ formula. Moreover, the procedure is not only fast but also gives cycle policies close to optimal.

Keywords: Joint replenishment, Multi-retailer, Economic lot scheduling, Heuristics

Determination of safety stocks in a lost sales inventory system with periodic review, positive lead-time, lot-sizing and a target fill rate

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An approximation for the fill rate, i.e. the percentage of demand being delivered from inventory on hand immediately, is derived for items in a periodic review inventory control system with lost sales. We assume demand is stochastic and discrete, lead times are positive and replenishments are made in multiples of a given fixed case pack size. Most literature on inventory control systems assumes that unmet demand is backordered. The major reason for this is that the analysis of a general lost sales inventory system is known to be hard. To find an approximation for the fill rate, given a safety stock, we use a combination of three techniques: we apply linear regression using both analytical expressions for the service level and the results of simulation experiments in which all product- and demand-parameters are varied in a systematic way. The approximation is tested for a wide set of parameters and performs very well: the standard deviation of the approximation error for the fill rate is well below 1%. Since the approximations are very fast, this result enables inventory controllers dealing with a lost sales inventory system to set safety stocks in accordance with the target service level set by their management in an effective way.

Keywords: Inventory, Lost sales, Safety stock, Fill Rate, Approximation

Inventory rationing with multiple demand classes and different backorder treatments

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The current study on inventory system with multiple demand classes assumed that the classes have the same backorder treatments, which based on either penalty cost, service task or other criterions. However, due to the variation of the customer values, an inventory manager may have different treatments or policies regarding the backorders. In this study, we attempt to investigate this problem. The manuscript can be divided into two parts. In the first one, we develop an inventory model considering deterministic demand classes with different treatments (DT model). The model aims to minimize the costs of one class with a given service constraint of another. The closed-form optimal solution is compared with the backorders with equal treatment policy (ET model), and the result indicates that DT model may have a service result deviating from the target level. In this case, using a critical level to ration the inventory between two classes (Different Treatments with Rationing model, DTR model) should have results outperforming the DT model, in terms of both cost and service level. The second part of the manuscript extends the research to stochastic demand case. We still consider two demand classes with Poisson distributions. We use the Deshpande (2003) approach to tackle the order quantity allocation problem with the consideration of multiple outstanding orders. However, since the (r,q) model with rationing policy and service constraint is too complicated to obtain closed-form formulas, we obtain the optimal solution through a wide range of search. Since the search is time-consuming, we utilize the properties in deterministic demand case to design a heuristic. The numeric results show that the heuristic performs the same solutions as the wide-range search does, which implies the rationing policy in stochastic case may has the same properties as in the DTR model.

Keywords: Multiple demand classes, Inventory policy, Backorder treatment, Service constraint, Rationing policy

Buyback and return policies for a book publishing firm

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The aim of the paper is to analyze a practical real world problem. A publishing house is given. The publishing firm has contacts to a number of wholesaler / retailer enterprises and direct contact to customers to satisfy the market demand. The book publishers work in a project industry. The publisher faces with the problem how to allocate the stocks of a given, newly published book to the wholesaler and retailer, and to hold some copies to satisfy the customers direct from the publisher. The publisher has a buyback option. The distribution of the demand is unknown, but it can be estimated. The wholesaler / retailer maximizes the profits.

The problem can be modeled as a one-warehouse and N-retailer supply chain with not identical demand distribution. The model can be transformed in a game theory problem. It is assumed that the demand distribution follows a Poisson distribution.

Keywords: Optimization, Newsboy problem, Game theory, Inventory control

Inventory management of platelets in hospitals: Optimal inventory policy for perishable products with emergency replenishments

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Platelets are short-life blood components used in hospital blood transfusion centers. Excluding time for transportation, testing, and arrangement, clinically transfusable platelets have a mere three-day life-span. This paper analyzes a periodic review inventory system for such perishable products under two replenishment modes (i.e., dual sourcing). Regular orders are placed at the beginning of a cycle. Within the cycle, the manager has the option of placing an emergency order, characterized by an order-up-to level policy. For this platelet inventory problem, we prove the existence and uniqueness of an optimal policy that minimizes the expected cost. We then derive the necessary and sufficient conditions for the policy, based on which a heuristic algorithm is developed. A numerical illustration and a sensitivity analysis are provided, along with managerial insights. The numerical results show that, unlike typical inventory problems, the total expected cost is sensitive to the regular order policy. It also shows that the optimal policy is sensitive to changes in the expected demand, suggesting to decision makers the significance of having an accurate demand forecast.

FORECASTING FOR INVENTORIES

Forecast information sharing in a two-stage supply chain with arima (0,1,1) demand

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The ARIMA (0,1,1) demand model has been analysed extensively by researchers and used widely by forecasting practitioners due to its attractive theoretical properties and empirical evidence in its support. A well known result in the supply chain inventory forecasting literature shows that the orders resulting from a downstream stage facing an ARIMA (0,1,1) demand process is also an ARIMA(0,1,1) process. Based on this mathematical relationship, various papers have argued that there is no benefit from any information sharing between downstream and upstream stages. On the other hand, it has also been shown in the academic literature that if orders faced by an upstream stage in the supply chain follow an ARIMA (0,1,1) process, it may not be possible for the upstream stage to infer the demand at the downstream stage since demand in the latter stage may be generated from various demand processes (including the ARIMA (0,1,1)). Therefore, information sharing in that case may be very beneficial resulting in reduction 0of forecasting errors and inventory costs. In this paper, using a two level supply chain, we explore different information sharing approaches between a retailer and a manufacturer when the retailer's demand process is ARIMA (0,1,1). The benefit of the Forecast Information Sharing is assessed empirically by means of experimentation on the sales data for 426 Stock Keeping Units (SKUs) from a major European superstore. Our empirical investigation allows insights to be gained into the value of information sharing in such a context of application.

An empirical study on demand models for a price-setting newsvendor

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We consider the price-setting newsvendor model where the ordering and pricing decisions for a product have to be made at the beginning of a selling period before demand is realized. The standard approach to model the price dependency of demand is to assume stochastic demand to be composed of a deterministic function decreasing in price, and a stochastic error term. The two commonly used demand models are the additive and the multiplicative models, where the main difference is the relation of price with variance and coefficient of variation of demand (see e.g. Petruzzi and Dada 1999). As a result of this difference the optimal policy parameters and the resulting profits also differ considerably.

One of the reasons for using additive and multiplicative models is the common usage of these models by practitioners and the claim that the two models can represent demand in an appropriate way in many cases. Especially in the marketing literature these models are the most commonly used ones when the effect of price on the total amount of demand is considered. However, the performance of the two models from a marketing and an inventory control perspective can differ significantly.

We present an empirical study which considers demand modeling in combination with price and inventory optimization. Using real world sales data of a retailing company, additive and multiplicative demand models are estimated and their adequacy of representing the data is assessed. Seeing the need and possibility of using a more general demand model we suggest estimating the demand distribution in a simple way which can cover different price-variance relations. Since using statistical tests for a-priori model selection does not necessarily result in better operational performance (see e.g. Syntetos et al., 2010), the optimal policies under each of the three models are evaluated according to their simulated profits. We conclude that additive and multiplicative demand models do not differ significantly in terms of their operational performance, but using the general model can increase profit significantly.

Keywords: Inventory control, Pricing, Forecasting, Demand modeling, Empirical study

Intermittent demand forecast by combining the forecasts from several methods into a composite one within MRO sector

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In the aircraft maintenance industry, forecasting the demand for spare parts proves to be very difficult due to the demand pattern experienced. This demand category is called intermittent demand and is characterized by the fact that in a lot of periods no demand is experienced. Forecasting the accurate demand in aviation maintenance requires accuracy, because both underestimating and overestimating the demand can result in large costs. Non available parts lead to unwanted downtime of aircraft on the other hand excessive numbers of parts are expensive to keep in stock due to high holding costs.

In this research study, nine forecasting methods were selected and applied to real life demand data from Fokker Services, six different combining techniques are applied to the forecasting methods, and their performance is measured by four different accuracy measurement techniques. The analysis showed that combining forecasting methods indeed increases the forecasting performance for intermittent demand. The study has presented a model that could be of great benefit to airline operators and other maintenance service organizations. It will enable them to select in advance the appropriate forecasting method that better meets their cyclical demand for parts. This approach is consistent with our objectives to compare different forecasting methods when faced with intermittent demand.

Keywords: Parts forecasting, Intermittent demand, Combining techniques, Aircraft maintenance

Demand classification: Exact and approximate solutions

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Spare parts management has received considerable attention in recent years, especially with regards to the evaluation of performance of various forecasting methods that may be used in order to estimate relevant inventory requirements. Demand patterns for such items are typically intermittent in nature meaning that demand arrives infrequently with many periods showing no demand at all. The standard method used in industry for forecasting intermittent demand requirements is Croston's method (CRO), although it has been shown to be statistically biased. A bias adjusted modification to CRO (Syntetos-Boylan Approximation, SBA) has been shown in a number of empirical studies to perform very well and be associated with a very 'robust' behaviour. Syntetos *et al* (2005, JORS) suggested a 2-parameter categorisation scheme which establishes regions of superior forecasting performance for CRO and SBA. This scheme was based on a theoretical analysis of the Mean Squared Error associated with these methods, expressed in terms of i) the squared coefficient of variation of the demand sizes and ii) the average inter-demand interval. The rule is approximate in nature and its proposition reflected a trade-off between accuracy and ease of operationalisation. The empirical validity of the classification scheme under concern was evaluated on 3,000 SKUs from the automotive industry and the scheme was found to perform very well. Kostenko and Hyndman (2006, JORS) revisited this issue and suggested a linear function to distinguish between CRO and SBA. However, no empirical results have ever been obtained on the performance of this rule and this constitutes the objective of our study. The empirical performance of both demand classification rules is assessed by means of experimentation on a large dataset for the purpose of developing our understanding on their comparative merits. In particular, we are interested on the extent to which the theoretical enhancement proposed by Kostekno & Hyndman matters from a practitioner perspective and how the theoretical gains in accuracy may be contrasted to the robust behaviour of the Syntetos et al. rule and the ease associated with its implementation in practice. Our work allows insights to be gained into the value of demand classification schemes for automated inventory management solutions; our paper concludes with some natural lines for further enquiry in this area.

Keywords: Spare parts, Demand categorisation, Forecasting, Stock control

The development of a classification model for predicting the performance of forecasting methods for naval spare parts demand

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In the South Korean Navy the demand for many spare parts is infrequent and the volume of items required is irregular. This pattern, known as non-normal demand, makes forecasting difficult. A forecasting strategy which simply generates a forecast using item time series is known as a direct forecasting. A forecasting strategy which derives a forecast for an item by prorating a forecast for the aggregated demand including the item demand is known as a hierarchical forecasting. Previous studies have found that the relative performance of forecasting methods that use hierarchical and direct forecasting strategies is conditional on some specific demand features such as variability and correlation. However, there has been little research on the guidelines for the selection of a forecasting method between hierarchical and direct forecasting methods for non-normal demand associated with spare parts demand. The aim of this research is to provide guidelines for the selection of a superior forecasting method for predicting spare parts demand using a classification model. This research uses data obtained from the South Korean Navy to compare the performance of forecasting methods for predicting the demand for spare parts.

The contributions of this research are to:

– identify demand features of the spare parts which significantly influence upon the relative performance of alternative forecasting methods that use hierarchical and direct forecasting strategies; and

– develop a logistic regression classification model for predicting the relative performance of the alternative forecasting methods for the spare parts demand by multivariate demand features.

Among forecasting methods tested a simple combination of exponential smoothing models was found to minimise forecasting errors and inventory costs. A simulation using real data identified that the logistic regression classification model reduced inventory costs, compared with the result only using the simple combination forecasting method.

This research proposes this classification model to guide the selection of a forecasting method for predicting spare parts demand in the South Korean Navy, so that it could maximise the operational availability of warships.

Keywords: Hierarchical forecasting, Spare parts demand, Non-normal demand, Classification, Simulation

Demand forecasting for single period risk-averse inventory control and pricing

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We consider the single period inventory control and pricing problem where the decision is based on the optimization of a risk measure such as Conditional Value-at-risk (CVaR) of profit or convex combination of mean profit and CVaR (see e.g. Jammernegg and Kischka, 2007, and Chen et al., 2009). However, the consideration of risk measures are reflected only in the optimization stage. But the whole process of inventory control and pricing consists of more than optimization. In this work, we specifically consider the effects of risk aversion on the demand forecasting and optimization steps, and present and evaluate different approaches of including risk aversion within the whole process of demand forecasting and inventory and price optimization. The immediate approach is to estimate the demand (error) distribution using classical demand forecasting and distribution fitting techniques and optimizing a coherent risk measure in the objective function instead of an optimization of expected profit. With this approach the risk preference is not considered during the entire process of estimation of the demand distribution.

Contrary, as the demand (error) distribution is the key for the stochastic inventory control problem, another approach is estimating the demand distribution in a way that it fits with the attitude of a risk-averse decision maker. While a risk-neutral decision maker considers every random deviation from expectation with the same weight, for a risk-averse decision maker different regions of the demand distribution have different importance, e. g. the lower tail of the distribution is more important than the rest of the distribution. After appropriately estimating the distribution, the optimization can be done based on expected profit maximization. We present an empirical study with real-world data of retailing companies where the performance of both approaches are evaluated against different performance measures, such as expected profit, profit variability, customer service levels and probability of loss.

Keywords: Inventory control, Pricing, Risk aversion, Forecasting, Empirical Study

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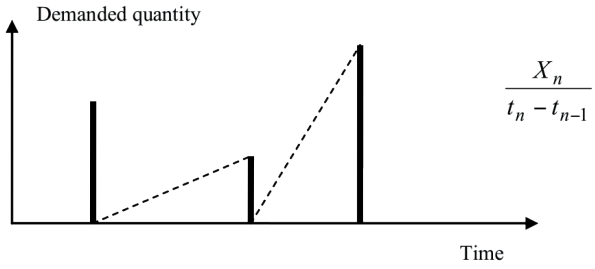

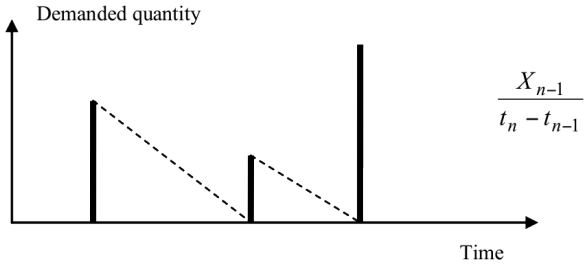

IMPLEMENTION OF INVENTORY MANAGEMENT THEORIES AND MODELS IN ORGANIZATIONS

Exploring the economic consequences of paying a supplier to keep a reserve inventory

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This work inspired by a contact with a larger telecommunication company. Many of the products offered are unique for this company and they also have very short lifetimes, normally about 18 months. Furthermore the suppliers do not wish to keep any inventories and they only accept orders on periodic basis, most often only once per month. In addition lead-times are long, as the suppliers are situated overseas. Therefore the company must keep all the inventories at considerable costs. The company wishes to make contracts with its suppliers such that they keep some reserve inventory that can be accessed (at a higher unit price than the normal one) but also with a shorter lead-time. Furthermore the company must also pay a cost proportional to inventory level for maintaining this reserve inventory. This problem can be considered as an inventory control model with two suppliers. We propose a dynamic programming model to assess the economic impact of such an arrangement and also present some numerical results from this model.

Hybrid contracting within multi-location networks

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The important concept of hybrid organisations has influenced organisational theory for the past 30 years. The idea behind hybrid organisations is to overcome the impediments of hierarchies as well as the impediments of heterarchies by combining both kinds of organisations. In hybrid organisations (e.g. franchise systems) a central instance, such as a central department, establishes guidelines and value bounds to align competing decentralised units with organisation-wide goals. The operational planning tasks are mainly executed by the decentralised sites within the pre-given bounds. In this context multi-location newsvendor problems for heterarchies and hierarchies have already been examined, but hybrid newsvendor models have not been presented so far.

The aim of this paper is to develop a new model which suits the antecedents of hybrid organisations. Based on the assumption that a central instance defines general conditions and bounds for the decentralised contracting process with respect to the privacy of local information we

1. develop a mathematical model in order to determine the bounds for contracting considering the different types of supply chain relations
2. analyse the implications of bounds on the decentralised contracting process
3. evaluate the approach in comparison to the results of centralised and decentralised planning strategies

The main effort of our approach is to find reasonable bounds for contracting without using local information. Thus, the model relies on estimated ratios and a specific structure of the contracting process.

Our findings indicate that the developed hybrid approach significantly improves the contracting results, even if cost information remains private for each site. We therefore conclude that the hybrid approach for multi-location newsvendor problems is an appropriate alternative to existing models, especially for planning within hybrid organisations.

Keywords: Contracting, Hybrid organisations, Multi-location newsvendor problem

A model to explore free-shipping policies of online retailers

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Internet retailers or the online divisions of brick-and-mortar retailers (henceforth referred to as e-tailers) often promote their products by offering free shipping on items if the total value of the order reaches a threshold (For example, jcrew.com recently had a promotion of "free shipping of all orders above $150"). The premise is that the promotion increases the total order value and total demand; and that the increased sales and that the extra margin will more than offset the costs of shipping.

In our experience, e-tailers, especially small ones, often use adhoc models to run free-shipping promotions. This paper develops and explores a model that will help e-tailers make trade-offs on how best to use the "free shipping" promotion. Based on empirical data, the paper develops a model for demand as a function of the free-shipping promotion and constructs tradeoff curves that the retailers can use to determine the best promotion strategy.

The model is unique for several reasons:

- based on field data it develops a function of demand as a function of the free-shipping promotion parameters (threshold value of free shipping and total order value)
- it encompasses all logistics costs– procurement, inventory, and transportation
-provides tradeoffs between increased order value, gross margins, and free shipping parameters.

Inventory performance of work flow control methods in make-to-order job shops

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In this paper, we measure 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 we evaluate include Kanban (Monden, 1983), CONWIP (Spearman, Woodruff, and Hopp, 1990), and POLCA or "Paired-cell Overlapping Loops of Cards with Authorization" (Suri, 1998). After creating a simulation of a balanced five machine shop operating at 80% utilization with uniformly distributed random job routings, we report inventory performance according to the system partition: ready jobs, jobs in process, and finished jobs. One of our main conclusions is that we find that flow control approaches do in fact reduce the number of jobs in process but total system inventory (as defined here) increases.

Role of VMI in managing supply chain

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Objective of study: The literature lists plenty of different supply chain techniques which aim to make the material and information flows more effective in supply chains. These are Quick Response in fashion industry, ECR in FMCG industry and CPFR in various industries. All of these supply chain techniques consist of several, sometimes overlapping management tools, such as electronic data interchange (EDI), vendor-managed inventory (VMI), continuous replenishment program (CRP), cross-docking, common planning and forecasting and activity based costing (ABC). Lee (2000), Van Goor (2001) and Varma (2006) argue that these management tools used by supply chains to share information and coordinate activities can be categorized into the groups of materials management, information management and performance & cost assessment toolboxes. Aim of the paper is to report about spread of VMI in Hungarian company practice, describe its nexus with other supply chain management tools and highlight the success factors and causes of pitfalls.

Materials and methods: When analysing the spread of VMI among Hungarian companies I use a database gathered by Department of Logistics and Supply Chain Management during 2007-2008 via an on-line survey. It contains the data of 70 firms about their logistics management practice. Database also makes it possible to examine which supply chain management tools are used together with VMI and which has to be implemented prior to VMI (as bedrock) and which offers a synergy. Besides the survey results the VMI success factors and pitfalls are discovered by case studies. Case studies are made at companies which either represent a success story or have already unmade it for pitfall reasons.

Results: Results tell that EDI or any other standardized information sharing tool is elementary for operating VMI and can be regarded as bedrock. Information shared is obviously covers inventory levels at cooperating partners and a common planning and forecasting system enhance its efficiency. Cross-docking could be an ideal realization of VMI. ABC as a supportive tool helps to detect the costs of customized inventory processes and discover sacrifice and benefits realized by cooperating parties. Conclusion Besides success factors revealed by Claassen et al. (2007) efficiency depends on the long-term view and intention of parties to trust each other. The level of trust and consequently the intensity and quality of shared information seem to be milestones in fruitful implementation.

A knowledge-based approach for crafting a strategic scm development program - A case study

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Crafting a strategic SCM development program is a multifaceted task. It is coupled with the strategic planning processes of the company, but, on the other hand, it is often necessary to plan the development of the SCM systems and organizations from the viewpoint of supply chain management. In this planning process the major challenge of SCM development lies in the nature of SCM thinking: it crosses the organizational boundaries. Development on the SCM area affects to daily work of numerous individual persons and organizational entities inside and outside the company boundaries.

This paper studies an approach to develop a strategic SCM development program. The approach is developed from two streams of knowledge management research results, knowledge maturity models and generic knowledge development strategies. From this basis the approach has three main characteristics. Firstly, the approach brings to the frontline mainly issues facilitating change and development in the area of SCM, not the SCM solutions themselves. The development area is divided to four major areas: 1) organization and responsibilities, 2) knowledge and skills, 3) data processing systems and 4) performance measurement and incentives. Secondly, the development is seen and represented as consequent logically connected development stages on the four development areas. Thirdly, the development program considers the question where in the organization the knowledge needed to climb the stages is expected to accumulate.

The research data has been collected during the development program process of a multinational manufacturing company and completed with interviews of the participants. As a result of the study a description of the actual process is presented and translated through evaluation of the research data as suggestion of a generic model for crafting a strategic SCM development program.

Keywords: Supply chain management, Strategic development, Strategic planning processes, Knowledge development, Case study

Process performance improvement in justice organizations - the pitfalls of performance measurement

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In terms of operations management, juridical processes can be considered as simple and straightforward job-shops consisting of manufacturing cells and buffers between them. Despite the apparent simplicity, almost every justice organization is facing difficulties to manage the work flow of the judicial cases. Obviously, the environment has different type of complexity, difficult to reveal with operations management terms and manage with operations management practices. This study to this complexity and focuses especially to problems related to one of the most popular contemporary improvement schemes for professional processes, applying performance measurement to manage the process.

The major challenge in applying performance measurement to professional processes is to ensure that the measures really bring forth desired behavior of the individual professionals. Wrong measures can cause unwanted effects like quality deterioration, distortions in process caseflow, excess in-process stocks and, as a result, prolonged and varying throughput times of the cases. It seems that in juridical environment it is difficult to maintain the balance between measuring quantity and quality, while the quantity is quite easy to measure, and quality extremely difficult. There are also strong indications that by selecting wrong process performance measures can severely distort the processes of the courts. This study aims to point out the problems in present process performance measurement in juridical courts, the consequences of selected distorting performance measures, and, finally suggest some solutions to avoid these problems.

As a research strategy the obstacles and problems as well as development characteristics and applicability of different solutions are studied in a case study on a Finnish court of appeal. The research data, interviews of the personnel has been collected before and after a process development project of the court. The researchers have also been able to collect participative observations in the project as development team members. The problem is also approached with a simulation model demonstrating how small unwanted shifts in the behavior of the professionals can cause prolonged throughput times. As managerial results the study presents some guidelines how to apply performance measures in professional organizations like juridical courts.

Keywords: Process performance measurement, Professional work, Juridical processes, Caseflow management, Case study

INVENTORY AND THE ENVIRONMENT

Firms' CSR and inventory policy

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In this article, we argue that firms that follow corporate social responsibility (CSR) policies will design a different inventory policy than firms that do not. In particular, we argue that there are two opposite effects at work. On the one hand, socially responsible firms that satisfy the interests of different stakeholders along the supply chain will receive from them firm-specific intangibles that will facilitate the coordination of different tasks that are needed to implement inventory policies such as just-in-time. The result is a reduction in inventory level as well as variability. Additionally, in the case of perishable goods, socially responsible firms will avoid accumulating an excessive amount of inventories given that they may damage the environment in the event of not being sold. On the other hand, the satisfaction of stakeholders, like customers, related to the implementation of marketing policies, will lead firms to accumulate inventories in order to avoid stock-outs that would seriously damage the reputation of firms in front of their customers. The dominant effect between the above ones is an empirical issue. Our conjecture is that there is a non-linear relationship such that for low-medium CSR values, the customer effect is the most relevant. However, for intensive social responsibility policies that include different stakeholders, there is a reduction in the inventory level and inventory variability. Also, in this paper, we investigate the signalling role of inventories as a reinforcing mechanism to give further credibility to the implementation of socially responsible policies that put customers under the spotlight. We test these theoretical predictions by crossing two databases, COMPUSTAT, for financial data, and KLD for data on social responsibility. Our final database contains data on 4188 different US companies for the period 1995-2007. The results found conform to our theoretical predictions. The connection between CSR and inventory policies is a relevant issue because, on the one hand, there is a growing tendency for firms to behave in a socially responsible way. On the other, inventories are responsible for up to 87% of the total peak-to-trough movement in GDP. Thus, our results suggest that this tendency to incorporate the social dimension in firms' strategy should smooth out the overall economic cycle given that firms apply more intensive CSR policies in the expansive periods (decreasing inventories) rather than during the downturns (increasing inventories).

Environmental and economic analysis of a production-inventory system and its attributes using an input-output activity matrix (IOAM)

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An Activity Matrix (AM) summarises a company's activities and how these activities influence the company's performance. This paper develops the Activity Matrix from an input-output representation of a manufacturing (production-inventory) system. The AM represents the activities of a manufacturing system and how they transform an organisation's inputs into physical attributes (outputs) such as products and waste and into other attributes that measure the organisation's performance such as profit and energy expended.

The paper describes how to represent the economic and environmental performance of manufacturing systems. The analysis examines the product life cycle of the products produced by the organisation. A concurrent enterprise (CE) context is used to examine the manufacturing organisation. The paper considers how the revised Activity Matrix representation of the manufacturing system expressed as an input-output matrix is suitable for analysing the environmental performance.

The paper shows how the representation may be generalised by considering a manufacturing system as one tier of a logistics chain. In this form, the input-output Activity Matrix representation considers how the activities within that tier affect the economic and environmental attributes of that tier. Similar representations may be derived for other tiers and so matrices can be derived for the complete logistics chain. The paper considers how the input output Activity Matrix representation is suitable for analysing the environmental and economic performance of complex logistics chains. Some suggestions are made about how this can be done. For illustrative purposes, the paper applies the IOAM method to analysis the environmental and economic performance of a simple production-inventory system.

If the relationships between the activities and the attributes are known or can be determined, then the matrix representation can be used as a systems design tool. Adding flexibility to the approach allows other system attributes to be considered and hence allows systems analysts to investigate other consequences of interest such as the social implications of the changes.

How many times to remanufacture?

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Protecting the environment has become a social and economic priority in many countries. Recycling material, reuse and remanufacturing of components of used products are inevitable options to reduce waste generation, exploit natural resources more effectively, and reduce the disposal of hazardous materials into the environment. Accordingly, the management of recycling, repair and remanufacturing processes is an area of interest both to practitioners and academics, giving rise to the term Reverse Logistics (RL).The emphasis on managing inventories is apparent in the RL literature. The Economic order quantity (EOQ) model has been the corner stone from the earliest reported work to the most recent. A common finding in these models is that the inventory policy shifts between two extremes; i.e., 'dispose all' or 'recover all'. These models also shared a common and unrealistic assumption that an item can be recovered indefinitely. However, many researchers acknowledge that a product cannot be recovered (remanufactured or repaired) indefinitely. Material degrades in the process of recycling losing some of its mass and quality. The option of 'multiple recovery' requires a significant investment in materials and components to extend the useful lives of products and to avoid the failure of components during disassembly and reassembly operations. This paper addresses the question of how many times a firm can recover a given product. A mathematical expression that estimates the number of finite times an item can be recovered is developed. This expression is then incorporated into two prominent models that were selected from the literature and the results for these models are compared to those of their original assumption of recovering an item indefinitely. The study found that assuming indefinite product recovery produces misleading results and does not capture the benefits that product recovery programs are supposed to bring. The results also suggested that as the number of times recovering an item increases, the percentage of available used units that are recoverable plateaus at a constant value. In addition, it was also found that there are an optimal number of times to recover a product that balances the investment costs with remanufacturing costs. The study also found that if the percentage of used units collected increases, the significance of ignoring the finite remanufacturing case worsens.

Consignment Stock for a two-level supply chain with entropy cost

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The economic order quantity (EOQ) model developed by Harris is the classical and earliest model for inventory management. The EOQ model has been the cornerstone for many models in inventory, supply chain and logistics management. Few researchers have critiqued the EOQ model on the basis that its assumptions are rarely met, and have called to think outside the box of classical inventory. One of the non-classical views in inventory management postulates that the behaviour of production systems very much resembles that of physical systems. Such a parallel between these systems suggests that improvements to production systems may be attained by applying the first and second laws of thermodynamics to reduce system entropy (or disorder). The idea of bridging thermodynamics and management science/operations research dates back to the mid of the past century. A recent study modelled commodity flow (demand rate) as a heat flow in a thermodynamic system. By using the first and second laws of thermodynamics, an entropy cost function was developed and added to the classical cost components, i.e. the order and holding costs of an EOQ model. The rationale for entropy cost is to account for the difficulty in estimating the hidden costs inherent in inventory and production systems. They suggested that larger lots are cheaper to control than smaller ones. Besides, ordering in smaller lots may intuitively be linked to environmental performance, as it quickens the flow of products along a logistic chain, resulting in faster rates of waste generation and depletion of natural resources.

Coordinating order quantities in supply chains is one of the popular policies that have been receiving growing interest from researchers and practitioners, as it results in savings and reinforces partnership between adjacent stages. A coordination policy that is widely applied in industrial relationships today is the 'Consignment Stock (CS)', was initially observed in an automotive manufacturing company. This strategy requires that relevant information is continuously shared between the vendor and buyer in a supply chain. A CS policy usually reduces the vendor's inventory since it uses a cheaper location (buyer) to stock its inventory. In return, the vendor guarantees that the buyer's demand is always satisfied and that the buyer pays for the items once they are withdrawn from inventory. This paper revisits a CS model by applying the second law of thermodynamics to reduce the entropy cost of the supply chain.

The economic and environmental performance of dual sourcing

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Traditionally supply chain management decisions are based on the economic performance of the involved parties which can be expressed by (non-) financial measures, like profit and customer service. But studies have shown that environmental criteria become more important. At the moment, the focus of the discussion lies on CO2-emissions which strongly accelerate the greenhouse effect. In this respect prevalent strategies, like outsourcing, off shoring or centralization, have to be reconsidered; the consideration of environmental criteria force companies to search for supply chain strategies that are at the same time cost-efficient, reliable and environmentally friendly. We illustrate this issue by using a dual sourcing strategy, i.e. a company (retailer) uses an offshore as well as an onshore supply source. The offshore source is cheap but inflexible. The onshore source is close to the market and can deliver immediately. In this context, we present a dual-sourcing model based on the newsvendor framework. We extend the model by including, first, emission costs for transport from the offshore source, assuming that (nearly) no transport emissions arise when ordering from the onshore source. It can be concluded that with increasing emissions costs the company sources less from offshore. Thereby, the transport emissions are reduced but as a negative side-effect the profit is lowered as well. Second, we assume that an emission trading scheme (ETS) is valid for transport activities. An ETS is a cap-and-trade system under which companies receive a certain number of emission allowances free of charge. One allowance certifies the right to emit one ton of CO2. If a company exceeds the emission limit, i.e. it emits more CO2 than covered by the certificates; it has to buy additional certificates, thus incurring cost. In the opposite case, it is able to sell the remaining certificates, thereby generating revenue. In this type of model, the optimal decision turns out to be a two-sided control-limit policy. It can be shown that by reasonably setting the emission limit the environmental impact of transport can be reduced and the economic performance measures are not harmed. Our findings are illustrated by numerical examples. From the results of the sensitivity analyses we conclude that the model can provide decision support for companies and can also be used to derive implications for policy-making.

Energy implications in lot sizing

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The earliest models of batch production were derived from the basic EOQ (Economic Order Quantity) formulation developed by F. W. Harris in 1913. In the 20th century several mathematical models have been proposed to optimize the size of the inventory and the orders under different assumptions, such as finite production rate, backorder/lost sale, variable holding costs, or using different modelling approaches like the discounted cash flow instead of the average costs.

In spite of the huge number of contributions emerged up to now, to the best of our knowledge, no contribution has been directly addressed to the investigation of Energy Implications in Lot Sizing.

In the modern manufacturing, energy is acquiring a growing strategic role, being fundamental to guarantee economic levels of productivity and at the same time an efficient use of natural resources. The contribution of energy to production is particularly relevant in specific industrial sectors, such as food processing, production of Silica bars, steel and primary aluminium. In these sectors, energy is a fundamental "raw material" necessary for both production and services. This consideration led practitioners to focus on technical solutions allowing the reduction of energy consumption per unit produced and/or energy waste, so as to gain competitive advantages. Frequently, such technical solutions impact on inventory features, stocked quantities and their management.

The work proposed, looking jointly at the economic value and energy content of the products, as well as the energy efficiency required at different production levels, aims at offering a novel framework for dimensioning lot sizes based on both economic and energy implications in the production process. Moreover, it should be noted that, while introducing energy as a key factor in the lot sizing assessment, an increased attention for the sustainability of the production-inventory system is introduced, too, due to the strict link between energy and environmental concerns.

Investigating city logistics: An empirical study from Piedmont

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Transportation of goods in cities is a very much debated issue. Cities were founded as centers for the exchange of goods; also, they import goods no longer produced in the metropolitan area (e.g., food). But transportation of goods towards cities is a twofold problem: on the one hand, the city needs inflows of goods and the social life of the city itself is impacted by the distribution of goods; on the other hand, the distribution of goods impacts the air pollution and traffic congestion.

For this reason, in recent years some cities have started city logistics projects to reduce the impact of the much needed distribution of goods towards the city center.

The Piedmont region (4.5 million inhabitants) in northern Italy has launched a research project to investigate the opportunities to design city logistics systems. Data were collected in all major cities (from 910.000 to 31.000 inhabitants). Also, various types of recipients were investigated and thus various categories of goods ranging from fresh and frozen food to liquids and packages.

Research method: This is an empirical study based on surveys. The unique feature of the study is that both persons in charge of transporting goods in the cities and people being delivered were investigated. Thus in our study we could investigate both the demand and supply side of the market for distribution services. Overall more than 1500 interviews were performed.

Main findings: The wide spectrum of data opens the door for various analyses. The most relevant findings from a policy making standpoint are:

- In larger cities a significant portion of the flows are born in the city itself; this challenges the efficacy of public logistic Distribution Centers in the city's outskirts at least for large cities;

- Currently the most common action to reduce traffic are time windows to enter the city center; however, data show that these constraints simply concentrate traffic in some specific hours thus contributing to traffic congestion rather than reducing it. So measures meant to reduce pollution actually contribute to it.

- Truck saturation is investigated in terms of volume, weight and time (i.e. ration between time available in a working day and time required to perform deliveries); data show that saturation of time is quite a crucial issue. This makes the distance between points of delivery and speed in the city issues that matter both from the environmental standpoint and the economic standpoint.

RISK MANAGEMENT IN SUPPLY CHAIN INVENTORY SYSTEMS

Secure supply chain management: A privacy-preserving data gathering approach

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Nowadays in competitive and dynamic market conditions, the effective collaboration of partners and coordination of all activities within the supply chain is of great importance as the implementation of a collaborative system leads to: (a) quick response to market demand, (b) matching supply and demand, (c) global optimization instead of local optimization of the whole system, (d) long term and mutual benefit partnership, (e) on line access to any data in the whole system, such as point-of-sale market and inventory information through global network, (f) producing and ordering the required items just in time for their consumptions to maximize the integrated total profit, (g) global competition. However keen competition between the parties of supply chain exists. The development of a privacy preserving joint-ordering policy could allow supply chain collaborations to take place without revealing any participant's data to the others, reaping the benefits of collaboration while avoiding the drawbacks.

In this paper we tackle the problem of secure supply chain collaboration using privacy preserving data-gathering protocols for the secure and anonymous gathering of database records from separate entities into a unified database, as described in. We propose that these protocols, based on e-voting, satisfy the security requirements of the problem.

Keywords: Supply chain management, Privacy-preserving data gathering, E-auction, Cryptography

An assessment model to evaluate supply chain resiliency: Application in the assembly industry

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In the last few years attention of the literature related to flexibility and supply chain has significantly focused on risk management issues. Many authors have dealt with supply chain vulnerability ranging from the study of the different risk sources to the development of solutions to manage properly risk in the supply chain.

The limitation of the current knowledge provided in the literature is the scarce use of empirical evidence: some contributions are purely theoretical and few are based on case studies. Besides, limited attention has yet been paid to investigate how companies are actually responding to risk, thus there is still limited evidence regarding the actual resiliency of companies to supply chain disruptions.

This work aims at moving a step forward towards the understanding of how companies are managing their resiliency. Specifically this work wants to develop an assessment model to evaluate the extent to which companies are implementing risk mitigation practices. Attention is here paid also to the understanding of the specific context in which companies operate in order to be able to compare different risk conditions. For this reason the assessment model evaluates both the relevance of risk and the practices adopted by the specific company. The model development was based on two steps. First we reviewed literature regarding Supply Chain Risk Management (SCRM) in order to identify practices related to supply chain resiliency capabilities. Based on this literature review a first draft version of the assessment model was designed and operationalised by means of a questionnaire. Second, in order to check for the validity of the model and to verify the discriminant capability of the questionnaire, case studies were conducted. We selected five Italian companies belonging to the assembly industry and used the questionnaire to assess their practices. Based on these case studies the questionnaire was fine tuned and its assessment capabilities were verified.

The paper provides an interesting contribution for both researchers and practitioners. The designed model is able to evaluate the firms' capability to reduce their vulnerability and to react when an adverse event occurs. This model will allow to compare SCRM practices in different contexts so to identify when specific practices are most applicable. Finally, we will be able to assess the relationship between the extensive implementation of SCRM practices and the operational performance achieved by companies (i.e. inventory levels).

Keywords: Supply chain resiliency, Supply chain risk management, Risk assessment, Assembly industry

Transfer of newsvendor inventory and supply risks to sub-industry and the public by financial instruments

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The management of inventory and supply risks of the newsvendor due to demand uncertainty are fundamental issues in the inventory literature. In this paper we argue that these risks can be pooled and shared among different supply chains and can also be transferred to the public via financial derivatives, provided that suppliers' short lead-time capacity allows retailers to replenish in the season. Consider a sub-industry of a certain family of short life-cycle products in which *m* suppliers have comparable production capability to produce goods for *n* retailers that are selling non-identical products. Such reserved capacity is treated as a commodity and is referred to as "super capacity". It is proposed that super capacity has its own value and its independent market price because retailers can hold it as an alternative inventory to reduce the cost of mismatching between supply and demand. In a two-stage newsvendor model, retailers buy super capacity in terms of *futures* and *options on futures*, and physical goods to create their inventory portfolios in stage one. In other words, they determine their inventory and hedge positions by holding products and super capacity before the selling season. Suppliers can also use the same financial instruments to hedge against both commodity quantity uncertainties and price risks. The existence of a unique Nash equilibrium in stage one shows that the trading of capacity is an efficient means for both hedgers and speculators to share risks under uncertainties. After realization of the demand is observed in stage two, the retailers decide the amount of on-hand super capacity to convert into inventory. Then they play a cooperative game to exchange the residual super capacity among supply chains. We show that the whole sub-industry is better off with super capacity trading even outside speculators exist. The contribution of this study is that we design a new mechanism by combining operational and financial hedging strategies to reduce and share risks in a sub-industry and with the public that are caused by stochastic demand. Our results indicate that the transfer of risk may be materialized among retailers, suppliers, and speculators under this mechanism. The independent market price of super capacity plays a crucial role in capacity allocation. This mechanism offers a new way of sharing supply chain profits between suppliers and retailers in the presence of production postponement risk.

Parameter determination for production/inventory control in the case of stochastic demand and different types of yield randomness

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In environments where not only customer demand is stochastic but also production is exposed to stochastic yield, inventory control becomes an extremely challenging task. In many practical situations linear rules are applied for production/inventory control in this case where the two risks are treated separately by a safety stock and some yield inflation factor that accounts for yield losses. In general, for reasons of simplicity, these control rules which e.g. are found in MRP calculations are chosen to be of a linear type. Though we know from theory that this simple type of control rule is not optimal, from earlier research it is well-known that this rule works quite well in the case of zero production lead times if the control parameters are determined in a sound way. Just recently it has been investigated how an effective parameter determination can also be extended to cases with arbitrary lead times. Up to know all contributions in this research context refer to production environments that are characterized by stochastically proportional yield. In our research we will extend the parameter determination approaches to two further well-known types of yield randomness, namely binomial and interrupted geometric yield. The three mentioned yield models mainly differ in the level of correlation existing for individual unit yields within a single production lot. We show how for all yield models safety stocks can easily be determined following the same theoretic concept. Because in the case of non-zero lead times these safety stocks vary from period to period, we additionally present approaches of how these dynamic safety stocks can be transformed into static ones. Finally, we show that under interrupted geometric yield also the yield inflation factor turns out to be time-dependent. For this reason we develop an additional rule for transforming this factor into a static parameter.

Measuring the risk in substitutable newsvendor models

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Despite the increasing academic focus on operational risk, decision support tools that help evaluating the value and risk of different portfolio strategies are not yet available. Furthermore, existing academic work is mostly limited to measuring the risk in single-item settings. The objective of this work is to consider the operational risk of assortment planning strategies in dynamically changing uncertain agile industrial environments; such as fashion and sports apparel and equipment, electronic devices, movies, games. Particularly, we study the optimal portfolio and the risk of its profit, by integrating the mean-variance Markowitz model from finance and the multi-item substitutable newsvendor model from operations, while carefully considering interdependencies in the assortment, such as demand correlations, substitutability and the connection between these parameters. This paper introduces a heuristic approach to a portfolio-risk minimization problem with consumer directed substitution. The model is studied by complex instances of the problem, which are considered as possible situations in the industry. The numerically tractable stochastic programming formulation proposed handles complex industrial problems and, as such, is potentially useful for producers under the process of product-portfolio building and production planning.

Vendor buyer inventory models with discrete delivery order, random machine unavailability and lost sales

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Inventory cost is one of significant cost in many companies. The inventory cost mainly consists of ordering cost, holding cost and delivery cost. Deciding how many order quantity and when to order is still a challenge to managers in both manufacturing and service industries. Some industries implement Just in Time (JIT) system to reduce their inventory cost. They ask vendor to send item when it is needed and in small batch, so the item inventory can be kept as low as possible. Vendor supply reliability is one important factor to support an efficient JIT system, however many vendors have an unreliable production system. For some reasons the vendor cannot deliver product to the buyer when it is needed, so the buyer will suffer because of lost sales.

In this paper a model of integrated single vendor single buyer is developed. Some research showed that vendor buyer integrated model has better performance than non integrated model in supply chain. Vendor and the buyer can share their costs to achieve global optimum supply chain. The model is operated in just in time system where buyer can set how many items should be ordered and how many items should be delivered in one shipment and the buyer pays the transportation cost. The vendor apply economic production quantity (EPQ) model. Ideally, machine will start production run when inventory level equal to zero. In some periods, there is a possibility that machine is not ready for some reasons such as for regular preventive maintenance. If this situation occurs, the vendor cannot deliver some predetermined quantity ordered by the buyer and the buyer will have lost sales.

We develop two vendor buyer models with random machine unavailability and shortage. The study considers lost sales, and two kinds of machine unavailability distributions. We assume that vendor machine unavailability is uniformly and exponentially distributed. The classical optimization technique is used to derive an optimal solution. Numerical examples are provided to illustrate the theory. Key parameters changes that affect costs are shown in the sensitivity analysis. From the results of the sensitivity analysis, it is shown that random machine unavailability parameter and holding cost have significant effects on the optimal total.

Keywords: JIT, Inventory, Unreliable machine, Buyer risk, Integrated model

Collaboration for a closed-loop deteriorating inventory supply chain with multi-retailer and price-sensitive demand

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Products such as IC chips, computers and mobile phone can become out of date due to technological innovation. However, these outdated products can be remanufactured and resale to market. In this paper, a closed-loop supply chain inventory system with multi-manufacturing cycles and multi-remanufacturing cycles is analyzed using sequential and global optimization. In the case of sequential optimization, the decision is made initially by the down-stream player, then by the up-stream player. In the case of global optimization, the decision is made jointly by all the players. The supply chain includes a manufacturer and multiple retailers with price-sensitive demand. This paper considers out of date as a type of deterioration and discusses the case of single-manufacturing cycle and single-remanufacturing cycle. The analytical results of this study show that a significant increase in the joint profit will result when the integrated policy is adopted.

Keywords: Supply chain management, Closed-loop supply chain, Multi-retailer, Deterioration, Price-sensitive demand, Collaboration

SERVICE LOGISTICS

The use of selective emergency shipments for fulfillment of differentiated service contracts for capital goods

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To service capital goods like medical systems or defence systems, OEMs increasingly offer performance based service contracts for system upkeep to the users. Because users may value downtime differently, service contracts may contain various performance levels. In practice, often a one-size-fits-all approach is used for service contract fulfilment. In this approach, all customers receive more or less the same service, irrespective their service contract.

In the literature, the main focus is on strategies for applying differentiation in spare parts supply. One approach known to be effective is the so-called critical level policy, where spare parts are reserved for premium customers once the inventory level drops below a certain threshold. Practical drawbacks of this policy are a lack of acceptance from customers with regular contracts and an unwillingness of service engineers responsible for system repair to postpone their work when they know that spare parts are on stock.

As an alternative, we consider selective use of emergency shipments in case spare parts are out of stock. Now, the supplier always uses on-hand stock to meet demand. If no spare part is available, we assume that we can use an alternative sourcing option (e.g. direct shipments from a central warehouse) at additional costs. We can use this option selectively, i.e., depending on part characteristics and customer class. We compare the performance of our new policy to that of a simple "one-size-fits-all" strategy and a current critical level policy.

We develop a multi-item single-location inventory model based on Dantzig-Wolfe decomposition with the goal of minimizing system costs under restrictions for the mean aggregate waiting time for each customer class. Based on an extensive numerical experiment, we conclude that:

- Selective use of emergency shipments outperforms the one-size-fits-all approach as is common in practice.
- Under specific conditions, e.g. if the emergency shipment costs are high compared to spare parts holding costs, our new policy is more effective than current critical level policies. Otherwise, critical level policies tend to be more efficient.

Keywords: Spare parts, Inventory, Service differentiation, Emergency shipments, Dantzig-Wolfe decomposition

Periodic-review (s, t) policies for distribution systems with multiple retailers and stochastic demand

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We consider a distribution system that consists 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. This paper develops a periodic-review inventory control policy for the system under which the central warehouse acts as a cross-docking point, where no inventory is carried. The retailers are replenished in intervals that are integer multiples of a basic replenishment period. We provide an exact evaluation of the long-term average system costs for a single joint replenishment interval under the assumption that stock can be balanced among the retailers. The structural properties of the inventory system are characterized by multi-modularity analysis. Our numerical results indicate that time-based and stock-based replenishment policies are asymptotically equally effective for large distribution systems with many retailers. Time-based inventory control policies can outperform stock-based inventory control policies in some settings. These findings provide insights, which are useful in the development and analysis of multi-echelon inventory systems.

A simple algorithm to determine optimal base stock levels in a two-echelon spare parts network

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In the military world, lead times at external suppliers are often very high (up to more than a year), which means that defense organizations need a large number of spare parts to cope with this lead time. Such defenses may use a joint central warehouse to reduce the total amount of required spare parts. We want to compare the situation of having N local stock points (the defense organisations), each facing a long lead time, with the situation of having a central warehouse in addition, such that the warehouse faces a long lead time and the local stock points face a short lead time. Since we consider very low demand items, we assume that we may use continuous review (S-1; S) (one-for-one replenishment) in both networks. However, for the two-echelon network, it is not known in the literature how to set the base stock levels S optimally. Using penalty costs (no service level constraint), Axsäter (1990: Simple solution procedures for a class of two-echelon inventory problems) has determined the penalty and holding costs that will result from given base stock levels, but he uses enumeration between some bounds to determine the optimal base stock levels. For the same model, we propose an algorithm to set the base stock levels, and we proof that the algorithm always finds the optimal levels.

Keywords: Spare parts, Inventories, Two-echelon network, Optimal stocking

Pool based scheduling and inventory optimisation for service in complex system

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The present paper proposes a methodology based on integration of optimisation and simulation for supporting the service of complex systems, such as power plants.

The proposed system is focused on pool management by using simulation as framework for testing solution proposed by an intelligent optimiser able to investigate alternative solutions.

The research aim to present the benefits of the integrated use of modelling and simulation and AI (Artificial Intelligence) techniques for optimising schedule and inventory; the paper includes the experimental results obtained by the model LAPIS (Lapis Advanced Pooling Intelligent optimiser and Simulator) developed by authors to support decisions making in power plants service.

The Pooling Strategies for managing a set of complex systems, such as power plants involving combined cycles (Gas Turbine, Steam Turbine and related Generators), it is an innovative approach in defining criteria for serving the sites by clustering the machine in subsets able to guarantee timeframes compatible with time cycle for each item for optimising availability, costs and technical commercial constraints. Therefore in real problems the stochastic factors (i.e. spare part lead times and consumption, failures, inspection duration, etc) as well as the complex processes (i.e. component refurbishment, supply expediting procedures) requires decision support systems (DSS) and the use of stochastic simulation in joint combination with intelligent optimisation represent an innovative approach.

The proposed approach allows to optimise the inventory as well as the service schedule considering both quality (i.e. availability, service time) and costs; in the proposed case study the different contract elements (i.e. plant stop penalties, contract duration, terms for inventory reuse) in addition to technical constraints (i.e. intervals for inspections and revisions), require a complex model for the optimisation.

The paper proposes the LAPIS model description and general architecture as well as the methodology for the joint optimisation/simulation, in addition the case study on the power plant pool service is used as validation example and experimental results are proposed.

Keywords: Inventory management, Pool service, Simulation, Optimisation, Complex systems

A classification of joint maintenance and inventory optimization models

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When financial resources are scarce, the pressure to reduce working capital increases. Companies can prevent themselves of going bankrupt, even when making serious losses, as long as they can pay their current liabilities. The management of cash, inventory and debt can save the company. As inventory in some industries has a big influence on working capital, the reduction of the inventory might make the difference between surviving and failing. On the one hand, maintenance models often rely on the assumption of an inexhaustible number of available spare parts (e.g. Barlow & Hunter, 1960). On the other hand, focusing on the inventory policy might resolve in higher costs for maintenance (Acharya et al. 1986). The joint optimization of spare parts and maintenance takes into account the trade-off between maintenance and inventory policies. This joint optimization was found very beneficial, among others, by Ilgin & Tunali (2007). They were able to reduce total annual maintenance costs by 53 % for their case study. Several papers are published concerning the joint optimization of maintenance and inventory, but no survey is provided thus far. This classification paper will give an overview of the relevant literature on joint optimization of maintenance and inventory. As several types of inventories influence the downtime of a system (work-in-progress, repairable spare parts, non repairable spare parts, etc.), a first subdivision of the problems is made based on these types of inventory. A further subdivision is made on the maintenance and inventory policies used. The two major groups of maintenance policies are preventive and condition based maintenance. As well papers describing continuous review as periodic review are included in the review paper. The result is a literature review that will be part of a doctoral research. The goal of this research is to include a third component into the framework. As service companies also have to travel to their customers to repair the broken machines, scheduling and routing will be added to the models. This review functions as a starting point of research on the mobile repairman problem, a special case of after sales service management.

Keywords: Maintenance policy, Inventory, Spare parts, Safety stock, Survey

On the use of install-base information for spare parts inventory control

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Introduction: Traditionally, spare parts demands are forecasted using a time-series approach, in which from past data future demands are estimated. Yet spare parts demand is highly variable, as is widely known and moreover, obsolescence occurs regularly. In this presentation we will investigate install-base forecasting (IBF) of spare parts demand. This implies that one derives the spare parts demands from forecasting the install base. In this way we hope to obtain a much better demand estimate.

Objectives: Identify business cases for IBF, assess difficulties in applying it. Next develop methods to assess its value and to use its information effectively.

Materials and Methods: We will consider three industrial case studies, one at an aircraft manufacturer, one at a computer manufacturer and one with a railway parts supplier, where install base forecasting was attempted. Next we will do a simulation study on the value of install base forecasting in relation to black-box time series forecasting. Finally we give an overview of how the results of install base forecasting can be used in spare parts inventory control. To that end we consider inventory control with changing demand information.

Results: IBF can be applied if the OEM is keeping detailed information on the customer, because of safety or contract reasons. It is especially suited for slow moving items in a spare parts network with stocking points where the stocks are highly dependent on a few customers. This is on one hand a dense network with critical or unique items destined for a particular customer, or a fleet with a limited number of important customers.

IBF is useful if demand patterns of customers change drastically, by e.g. expiration of contracts or discarding of systems, with the extreme case that demands totally disappear.

IBF information can be used reactive (after a change has taken place) or proactive. In both cases the user can react quicker to changes. In the proactive case the user can even get rid of stocks in the natural way. In the reactive case the user either has to relocate stocks or discard them. In both cases inventory costs are decreased and in the first case obsolescence may be avoided.

Conclusion: IBF is a nice technique suitable for dynamic situations, but has heavy information requirements. Using the information is however not straightforward and requires a proactive approach. But when that is established much can be saved.

Keywords: Spare parts, Inventory control, Forecasting, Install base, Overview

Decision framework for spare parts management in an MRO organisation

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Companies that use and maintain high value capital assets, such as trains or military applications, usually consist of a number of local service companies in which the capital assets are maintained. Maintenance and overhauls are either planned or unplanned due to unforeseen breakdown of spare parts. Hence demand for spare parts is not known in advance exactly. These companies usually have a central stocking location for spare parts and stocking locations near the service companies. A spare parts management organisation is responsible for minimizing downtime of the capital asset due to non-availability of spare parts. A high system availability is desired because it either generates more revenues or it is important from a peace terms point of view (in military settings).

In spare parts management organisations, decisions are to be taken at the strategic, tactical and operational level. For instance, decisions need to be taken on forecasting, supply planning, inventory control and repair shop control. We present a framework in which the connection between these decisions in spare parts management organisations is outlined. Also a literature review is given on models that aid in making decisions within this framework. This framework can be used to increase the efficiency, consistency and sustainability of decisions on how to design, plan, and run the spare parts supply chain. This framework is the starting point for case studies that will be conducted at five different companies in order to test the practical value of the decision framework. The case study will show whether decisions can be marked as generic or company specific. It also gives insight in the quality of the decisions made in practice. First results on the case studies will be presented.

Keywords: Spare parts management, System availability, Decision framework, Decision support models, Case study

A model for performance evaluation and stock optimization in a kit management problem

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In this talk we consider a kit planning problem where demand occurrences are not for individual items, but for kits (a group of items). Each kit contains an arbitrary number of items. Kit demands occur according to a Poisson process. Whenever a kit demand occurs, only one item from the kit is used and the rest is returned as unused. The item that will be used from the kit is not known in advance and the whole kit has to stay at the demand site for the whole duration. The used item is replenished through a stochastic supply system, with possible capacity limitation. This model has applications in health care (planning surgical implant inventories), and repair kit management systems. As a demand for a kit triggers simultaneous demands for the items within the kit, the individual demand arrival processes for the items in that kit are correlated. Moreover, the items in the kit spend a common time together at the demand site until their return back to the inventory (except for the item that is consumed, which needs to be supplied through a supply system). Also, there may be items which appear in more than one kit. Therefore, finding the joint probability distribution of the number of items that are outstanding, and hence finding the probability of kit availability, is generally difficult. We can obtain these terms in a fairly explicit form under the assumption that an item which is not in stock when a kit demand occurs can be obtained through an emergency supply channel (with possibly high cost). In a system described above the objective of the decision maker is to decide on how many units of each item to stock in the inventory so that (1) expected holding costs will be minimized, and (2) pre-specified kit availability constraints are satisfied. Even though our formulation leads to exact formulae for the kit availability probabilities (and therefore enables us to evaluate the performance of the system for a given set of stock levels for the items), the optimization problem is highly intractable. Therefore we provide a heuristic procedure for optimizing the stock levels, and test the quality of the heuristic.

Keywords: Kit management, Performance evaluation, Correlated arrivals, Base stock policy, Service logistics

Spare parts inventory pooling games

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High-tech companies are often confronted with the difficult task of maintaining high availability of their technically advanced systems. When a critical component fails, it is important that spare parts are quickly available in order to prevent costly downtimes. Inventory pooling, which refers to an arrangement where demand at a stockpoint that is out of stock is satisfied from another stockpoint with a positive on-hand inventory, can be an effective strategy to reduce total costs.

We study a situation where several independent companies separately stock spare parts of the same item. For example, consider multiple airline companies that use the same type of aircrafts and independently stock spare engines at separate locations. They may cooperate by pooling their inventories. However, first the participating companies will have to be convinced that such an arrangement is beneficial for everyone and it will always be possible to divide joint costs amongst the members of a pooling group such that no subgroup of companies has an incentive to split off. In order to obtain insights into these issues, we use cooperative game theory. We define a cooperative cost game and examine the conditions under which such a game has a nonempty core, i.e. a stable cost allocation exists.

We assume that the inventory system at a company can be seen as being controlled by a base stock policy with a fixed base stock level. Furthermore, we assume Poisson demand processes with constant rates, the use of an emergency procedure in case of a stock-out, negligible transshipment times, and complete pooling of inventory between members of a pooling group. It follows from our assumptions that the stock-on-hand process of a coalition of companies can be modeled as an Erlang loss system.

Our analysis concentrates on cores of spare parts inventory pooling games, in which the characteristic cost of a coalition is the sum of holding costs and expected downtime costs. We first look at a base setting where companies are identical, for which we prove that the core of the associated game is always non-empty. Afterwards, we generalize this result 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.

Keywords: Game theory, Balancedness, Spare parts, Inventory pooling, Supply chain management

Redundancy allocation for serial systems

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We consider a situation in which a user buys a number of units of the same system. The system is composed of subsystems placed in a serial structure. At most two identical, repairable parts can be used in a cold standby redundancy setting in each subsystem. The systems are supported by a single spare parts inventory stock point. A predetermined emergency procedure is performed on stock-out events. Three policies, which are different combinations of applying the emergency procedure and having redundancy, can be implemented per subsystem. We formulate a model to minimize the Total Cost of Ownership of the systems under a minimum availability constraint. We conduct exact analysis and derive a number of results on the optimality of the policies on subsystem level. We also provide a method for the generation of an order of the subsystems that reflects the benefit of investing in redundancy.

Spare parts optimization in airport equipment maintenance

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We study a spare parts allocation problem in a single echelon inventory system with complete pooling characterized by expensive spares, long repairing time and a strict service constraint. The work is motivated by the practical needs of a large Italian logistics company handling 17 regional warehouses and supporting the activity of 38 Italian civil airports. When a failure occurs at some airport, a demand for a replacement is issued to the regional warehouse, which provides a new spare if locally available or re-forwards the demand to the closest warehouse with available spares. If no spare is available at any warehouse, an emergency request is issued to an external supplier. The contractual service level to grant for each item is the operational availability of all operational sites, which imposes high reliability of safety equipments. This requirement corresponds to a strict constraint on the total time spent for lateral transshipments and emergency requests. Therefore, the Spares Allocation Problem is the problem of finding an allocation of spares to warehouses which minimizes the overall cost for inventory holding, lateral and emergency shipments, subject to the constraint on the minimum operational availability of the system. This problem is formulated as a non convex integer program. Two assumptions are made on the structure of the problem: the cost for a lateral transshipment is proportional to the transfer time, and the time and cost needed for a transshipment between two warehouses is always smaller than the time and cost required for an emergency shipment. This special structure leads to prove properties of the cost function that in turn allows to design a new efficient branch and bound procedure. The lower bound is obtained by solving a reduced problem with convex objective function, solvable at optimality very efficiently. A new fast heuristic algorithm is also developed to find a feasible allocation within small computation time. Both algorithms are evaluated by using practical and realistic data from the Italian airport corrective maintenance context. Computational experiments demonstrate that the branch and bound technique is able to optimally solve almost all tested instances within reasonable computation time. The heuristic algorithm finds quite good solutions within very limited computation time, thus being a promising approach for finding feasible solutions to difficult instances.

Optimal inventory control of manufacturing/ remanufacturing systems with multiple quality grades

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In this paper we characterize the optimal policy structure for a manufacturing/ remanufacturing system wherein the returned items may have different quality grades. Returned items are graded based on the service time they need in order to be remanufactured. In the first model we investigate a case that returned items are differentiated based on the quality grades but after remanufacturing they can be considered as good as new items. We show the optimal policy is characterized by three state-dependent threshold levels. The second model considers a case wherein remanufactured items are differentiated from manufactured items. We also characterize the optimal policy structure in this case. In the last model, we investigate a case wherein the customers are also differentiated into high and low priority class customers. According to this model high priority customers must be satisfied through manufactured items stock and low priority customers can be serviced through both manufactured and remanufactured inventory. We also characterize the optimal policy structure for this system. With numerical analysis we shed light over the role of quality grading in hybrid systems. Furthermore, we compare our state - dependent policies with static threshold policies previously developed for these systems.

End-of-life inventory problem with remanufacturing control policies

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We consider the end-of-life inventory problem of a capital good manufacturer in the final phase. Final phase starts as soon as the production of parts terminates and continues till the last service contras expires. Due to service obligations, the manufacturer is obliged to place a final order quantity that suffices for the entire service period. Besides the final order quantity, there are other sources to obtain serviceable parts including remanufactured items and phased-out returns. Phased-out returns happen due to replacement of the installed base with a new system in the customer side and therefore, the phased out products are returned to the manufacturer. These phased out returns can be used later in time to satisfy the demand for service parts. However, the occurrence of phased-out returns complicates the problem since with the decrease of the installed base size in the market the demand for service is also decrease over time. Another source of complexity is the positive repair lead time to remanufacture the returned items. Since the holding cost of remanufacturable items is less than the remanufactured ones, therefore it might be beneficial to investigate which remanufacturing control policies suit this setting better. We consider various policies and according to each one we find the optimal final order quantity and the associated time-dependent remanufacturing policy. We compare all policies regarding the expected total cost in order to investigate which one outperforms the other.

Pooling through lateral transshipments in decentralized spare parts systems

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We study the inventory management problem of a service center operating in decentralized service parts network. The service center collaborates with another center through inventory and service pooling. Furthermore, the service centers collaborate through sharing information on the inventory status. Upon demand arrival, a service center may request a part from the other center, in which case a payment is made. Under this collaborative environment we characterize the optimal operating policy of an individual service center. Through computational analysis we identify the conditions under which the service center is most profitable and analyze different pooling strategies. Finally, we consider different levels of information sharing between the service centers to quantify the value of sharing information.

Keywords: Inventory pooling, Lateral transshipment, Management of service parts, value of information sharing, optimal control of stochastic systems.

Repairable item inventory control with work-in-process (WIP) dependent base-stock levels

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A new inventory control procedure is proposed for repairable items stock provisioning problem. The new control procedure, denoted by (S0; r), is a modified version of classical base-stock policy. Base-stock level of a repairable item is updated based on the WIP inventory level in repair facility with update frequency, r, modeled as a separate tactical control parameter together with a standard base-stock level, S0. Stock-out situations are handled by emergency shipments, and priority shipments are used when updating the base-stock level. A single-item single-location problem is considered, with repair facility having a limited capacity, and the problem is modeled by a two-dimensional continuous-time Markov chain, which is solved explicitly by using matrix geometric methods. Through numerical results we showed that, for a given demand fill rate, it is possible to achieve substantial savings in inventory on-hand by using the (S0; r) procedure. In addition, for a given set of inventory holding, priority shipment, and emergency shipment costs, it is possible to have significant decrease in total cost by an appropriate (S0; r) policy.

Keywords: Repairable items, Inventory control, Base-stock, Markov chain, Work-in-process, Spare parts

Hybrid lateral transshipments in a multi-location inventory system

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In managing networks of stock holding locations, two approaches to the pooling of inventory have been proposed. Reactive transshipments respond to stockouts at a location by moving inventory from elsewhere within the network, while proactive redistribution of stock seeks to minimize the chance of future shocks. This paper is the first to propose a hybrid approach in which transshipments are viewed as an opportunity for stock redistribution. We adopt a quasi-myopic approach to the development of a strongly performing hybrid transshipment policy. Numerical studies which utilize dynamic programming and simulation testify to the benefits of using transshipments proactively. In comparison to a purely reactive approach to transshipment, service levels are improved while a reduction in safety stock levels is achieved. The aggregate costs incurred in managing the system are significantly reduced, especially so for large networks facing high levels of demand.

Keywords: Inventory control, Lateral transshipments, Dynamic programming

Reducing costs of spare parts supply systems via dynamic priorities

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We study dynamic repair priorities in 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 fulfilled as soon as the repair shop has a ready-for-use item available. The objective of our study is to develop close to optimal dynamic priority rules and base stock levels that minimize the sum of inventory holding and machine downtime costs. When a failed item arrives at the repair shop we use real-time information on actual stock levels and demand rate forecasts to determine what item from the queue of failed parts is sent into repair. For small problem instances we use dynamic programming to find an optimal priority rule for the repair shop under given base stock levels. For bigger problem instances this is not feasible and we have developed two algorithms that fall in the class of approximate dynamic programming. The first algorithm is a one-step look ahead policy that uses Monte Carlo simulation to approximate the value function. The second algorithm looks at all jobs in the repair shop just after a new failed part has arrived, and then calculates the repair schedule that minimizes expected downtime cost until the last job in the queue would be finished. From this optimal schedule the failed part that appears first is actually put into repair. Next, we present a simulation-based optimization procedure to determine appropriate base stock levels for all repairables in the system. A strong advantage of this method over many other methods is that it can fully anticipate on the real-time job scheduling logic in the repair shop. Using a smart iteration scheme we can limit the number of required simulation runs such that the solution is not only effective but also efficient.

We compare our dynamic priority rules with static priority rules and simple FCFS. We show under what circumstances dynamic priorities rules are most beneficial. We also show the impact of the applied priority rule on the optimal base stock levels and when it is attractive to optimize the priority rule and the base stock levels simultaneously.

Keywords: Inventory/production control; Spare parts; Dynamic priorities; Approximate dynamic programming, Simulation-based optimization

Trade-off between spare part inventory investment and throughput time reduction for service contract fulfillment of capital goods

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For advanced capital goods like high-tech manufacturing equipment and medical systems, the manufacturers tend to expand their business by offering service contracts for system upkeep during the system life cycle. If system downtime is expensive for the user, a service contract typically contains quantified service levels to be attained by the service provider, such as a maximum response time in case of a failure or a minimum uptime per year that should be achieved. We encountered such contracts at Thales Nederland, a supplier of naval systems such as radars.

At the start of the contract, the supplier invests in spare parts to facilitate fast repair by replacement of failed modules, the so-called Line Replaceable Units (LRUs). If the service performance appears to be less than agreed upon during contract execution, the service provider should increase its performance. At a tactical level, options are a.o. (i) buying additional spare parts, (ii) reducing repair shop throughput times for the expensive repairable spares, and (iii) reducing transportation times of spare parts in the service network. In this research, we focus on throughput time reduction (of repair and transportation) as alternatives to spare part investment for multi-indenture, multi-echelon spare part networks. In the practice of Thales Nederland, such reductions are feasible at extra costs.

We develop expressions for the marginal backorder reduction of LRUs as a function of the marginal reduction in throughput time of each repair and transport in the service network. Combining these marginal values with a certain discrete step size for the throughput time reductions, we develop a heuristic optimization method to balance the investment in throughput time reduction to investment in extra spares. In an extensive numerical experiment, we show under which conditions it is more profitable to reduce throughput times than to buy extra spare parts. Furthermore, it is interesting to gain insight in the probability that the promised service level will be attained. As this is not easy to compute in general, we apply discrete event simulation for an initial study on the variability in the service contract performance. We illustrate our approach using a case study at Thales Nederland.

Keywords: Spare part inventory, Repair, Throughput time reduction, Optimization, Simulation

Integrating reliability centered maintenance and spare parts stock control

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In the classical approach to determine how many spare parts to stock, the spare parts shortage costs or the minimum fill rate are a key factor. A difficulty with this approach lies in the estimation of these shortage costs or the determination of appropriate minimum fill rates. In an attempt to overcome this problem, we propose to use the data gathered in reliability centered maintenance studies to determine shortage costs. We discuss benefits of this approach. At the same time, the approach gives rise to complications, as the RCM study determines downtime costs of the underlying equipment, which have a complex relation with the shortage cost for spare parts in case multiple pieces of equipment have different downtime costs. A further complication is redundancy in the equipment. We develop a framework that enables the modelling of these more complicated systems. We propose an approximative, analytic method based on the model that can be used to determine minimum stock quantities in case of redundancy and multiple systems. In a quantitative study we show that the method performs well. Moreover, we show that including redundancy information in the stocking decision gives significant cost benefits.

Service parts inventory control with lateral transshipment that takes time

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In equipment-intensive industries such as truck manufacturing, electronics manufacturing, photo copiers, and airliners, service parts are often slow moving items for which, in some cases, the transshipment time is not negligible. However, this aspect is hardly considered in the existing spare parts literature. We assess the effect of non-negligible lateral transshipment time on various aspects of spare parts inventory control. Furthermore, we introduce customer-oriented service levels by taking the uncommitted pipeline stocks into account. A case study in the dredging industry shows that lateral transshipment may lead to lower system performance, which supports the results from some recent studies. Furthermore, we find that considerable savings can be obtained when we include the uncommitted pipeline stocks in both base stock allocation and lateral transshipment decisions.

Keywords: Inventory control, Lateral transhipment, METRIC, Customer-oriented service level, Uncommitted pipeline stocks

Optimal maintenance and replacement decisions under technological change with consideration of spare parts inventories

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A relatively unexplored area of service logistics is the impact of technological evolution on spare parts inventories. Classical spare parts inventory models assume that the same vintage of technology will be utilized throughout the planning horizon. However, replacement often occurs in the form of a new technology. A consequence of such replacements is the rendering of existing spare parts inventories obsolete and the necessity to purchase a new set.

We propose to study the impact of spare parts inventory on maintenance and replacement decisions under technology change. We examine how spare parts inventory levels will influence the replacement decision and how much better a new technology must be in order to overcome the obsolescence of existing spare parts inventory. Papers that do address technological change in a related context usually only consider the replacement decision, ignoring the ability to repair the asset. All of the papers fail to consider the impact of spare parts inventory levels and compatibility on these decisions. We formulate this problem from an economical point of view where the maintenance and replacement decisions are viewed as investments to improve profitability versus necessary costs to be minimized. We model this problem as a Markov decision process where the decisions are made as a function of the state of the asset itself, the technological environment, and the current spare parts inventory. The actions available to the decision maker are to do nothing, repair, or replace the asset. The replacement decision is complex in that one must be decide with which technology available on the market to replace the current asset. Under technological change, the do nothing and repair options have significantly more value as they allow for the appearance of even better technologies in the future.

Spare part management with dual supply sources and two demand classes

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This research is motivated by an industry project of spare parts management for a major petrochemical company of China. For each major spare part, the company has two sources of supply, which are differentiated in their costs and lead times. In addition, there are multiple classes of demand for the spare part, which come from replacement or repairing requests from equipments of different critical levels. The firm aims to improve their existing inefficient practices of inventory replenishment and allocation of on hand inventory to different classes of demand to reduce the operational costs.

We develop a periodic-review, infinite-horizon, inventory system with dual supply sources and two service-differentiated demand classes. One supply source provides shorter delivery lead time but charges a higher cost than the other. The difference between the long and short lead time is an arbitrary positive constant. From the practical problem, unsatisfied demand from each class is backlogged and incurs different unit backlog costs per period. These two features make the problem very challenging to analyze and its optimal policies are unknown and expected to be very complicated to implement. Therefore, we adopt a base-stock type policy with two constant parameters to control inventory replenishment of the spare part. To effectively allocate on hand inventory to different classes of demand, we study two types of rationing policy: non-anticipated rationing policy and anticipated rationing policy. We provide exact evaluation procedures for the expected long-run average system cost under these control policies. We further develop easily computable lower and upper bounds of the optimal policy parameters, based on which an algorithm is designed. Finally, we conduct numerical studies with real data from the project to illustrate the efficiency of the solutions and compare the performance of two different rationing policies.

IN ABSENTIA

Inventory management of spare parts using ANN based on RFID information

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Due to unstable demands, it is very difficult to determine proper level of inventories in repair centers managing spare parts of electronic product. Since an electronic product has short life cycle, a repair center should hold sufficient inventories to satisfy the uncertain demand and to reduce waiting time. However, much inventory may require excessively high cost. Therefore, there exist tradeoff between inventory cost and service level. If we can forecast demand precisely, we can enhance service level as well as reduce inventory cost. To achieve this goal, gathering exact information from not only supply chains but also reverse chains is essential and RFID (Radio Frequency Identification) technology can be used for this purpose. In conventional approaches without real time data, forecasting future demands has been based on the past data. Therefore, it is impossible to forecast the demand of new parts having no data. In this paper, we suggest a method to forecast the demand of spare parts and manage inventories using RFID technology. We gather RFID information such as the date of sales, the volume of sales, the location of sales, the history of repair, and the cause of failure can contribute to more precise prediction of future demand. Using this information, Artificial Neural Network(ANN) is used to forecast the demand of spare parts in repair centers. In order to simulate our approach, we develop a prototype system collecting RFID data on the supply chain and the reverse chain and forecasting the demand. And we suggest appropriate inventory policy according to demands in order to raise service level. We perform simulation research to validate suggested method. We expect that our approach can support to raise the level of customer satisfaction and reduce inventory cost. In this paper, we perform the research based on real-time information which was extracted in supply chains and reverse supply chains. Because of real-time data such as product sales data and repair history data, the demand of spare parts is forecasted more exactly and we can suggest improved inventory policy.

Keywords: Spare parts inventory, RFID technology, Demand forecasting, Inventory policy, Utilization of history data

The influence of power and interest on designing inventory management systems

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It is widely acknowledged in literature that the design of Inventory Management Systems is of significant importance for the overall performance of manufacturing companies (Blinder and Maccini, 1991; Rabinovich and Evers, 2002). Although different definitions exist, Inventory Management Systems are generally described as integrated systems designed to integrate, standardise and automate decision processes related to the management and control of inventories (Nagarur e.a. 1994). Different studies have emphasized the existence of multiple stakeholders involved in the shaping of inventory systems (Konijnendijk, 1993; O'Leary-Kelly and Flores, 2002). Less attention however is paid to the process of shaping Inventory Management Systems and only few studies present empirical data how this process takes place (de Vries, 2009). In our study we focus on how the process of (re)-designing an Inventory Management System may influence the established relationships among stakeholders within the Production-Sales interface. In doing so, we concentrate on the power distribution and the interests of the stakeholders involved in this shaping and implementation process. In our full paper case data is analysed by applying a conceptual model which focuses on the interdependency between the (re)-design process of an Inventory Management System and the power and interests of the key-actors involved in this process. Noticeably, many of these key-actors have different interests and hold different sources of power. As will be illustrated by our case studies stakeholders assess how the Inventory Management System will affect interest and power relationships not purely on objective but also on subjective arguments. Our case studies suggest that this influences both the (re)-design process as well as the outcomes of this process. Our papers aims at contributing to the theory on inventory management by presenting a conceptual model which encompasses the role different stakeholders play during the process of (re)-designing and implementing an Inventory Management System. In doing so, we focus on the role of power and interests. Secondly, our full paper presents empirical case data aimed at exploring the complex mechanisms that take place between the stakeholders during this (re)-design and implementation process. Hopefully, this more in-depth understanding will enable practitioners to adopt more effective implementation strategies.

Keywords: Stakeholders, Case-study, Power interest

Improving the agility of a food distribution network: The case of a non-profit supply chain for the food insecure

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This paper focuses on the operational planning issues in a non-profit supply chain that distributes food for the "food insecure." Both the demand and supply are uncertain and hence an agile supply chain strategy is proposed.

The case walks us through the current situation and detailed plans to improve the efficiency and effectiveness of the operations to improve the quantity of food reaching the "food insecure."

Also, using "push-pull" analogy, "3-S" conceptual framework and humanitarian logistics partnership theory, the supply chain strategies and tactics are analyzed.

The literature research focuses on bringing out the salient issues and practices in supply chain management for domains with uncertainty in demand and supply.

Background research suggests that for supply chains that face uncertainties in both demand and supply, "agile" techniques that includes moving away from a pure "push" system to a "push-pull" system, and focus on a process approach to supply chain integration that addresses both efficiency and effectiveness improvements are critical.

In addition, the 3-S framework highlights the importance of improving structural synthesis, supplier and customer synergies along with the synchronization of the logistics.

Lastly, the humanitarian logistics theory points to the importance of integrative partnerships to sustain long term performance.

The case research addresses how these concepts are applicable in the non-profit domain. Essentially, demand planning, supply coordination, and logistics integration are key drivers for making the supply chain agile.

The study clearly establishes that structure of the supply chain has tremendous impact on the efficiency of the operations.

Also, managers running non-profits should focus at demand management in a very proactive manner.

Material flow optimization in a multi-echelon and multi-product supply chain: Comparison of an exact and heuristic approaches

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In the recent times, the performance criteria in many organizations have transformed the structure and operational requirements of distribution and supply chain networks. The performance could be in terms of responsiveness or the cost associated with the supply chain. This paper addresses a case involving reduction of the cost considering the logistics and distribution part of a real-world supply chain. Motivated by a project with a leading writing notebooks manufacturer (In India), this paper addresses the optimal flow of materials (notebooks) across the supply chain. The objective of this study is to minimize the total cost involved in production and distribution of the goods across the supply chain. The two types of cost associated with flow of materials are unit cost of transporting the goods and the fixed cost of operating the different types of vehicles for transporting these goods across the supply chain. The particular scenario that we consider has four stages, source (supplier), converters, hubs, stockists and the wholesale distributors. The demand at each stage is the consolidated demand of the corresponding downstream stages. The final demand is at the wholesale distributors, which is at the extreme downstream of the supply chain. The demand for each product is assumed to be known for every period of the entire planning horizon. We have developed both a mixed integer linear programming (MILP) based optimization model and a heuristic method for solving the distribution problem. The MILP model is a generalized capacitated model consisting of both fixed truck cost and the variable transportation cost. The MILP model includes allocation of stock across the supply chain and transporting them to desired location, depending on the truck availability and the truck cost. The heuristic method proposed in this study consists of two stages, in the first stage a multi-stage distribution problem is solved based on the "total opportunity penalty cost method" (TOPCM) and in the second phase a "branch-and-bound" (B&B) algorithm is developed to solve the truck allocation model. The solution obtained in two stages of the heuristic method are combined and compared with the solution obtained in the MILP model.

The proposed heuristic performs really well (under 10%) when compared to the MILP model and is extremely quick. The model was coded in CPLEX and the solution method in C++.

RFID technology as a strategic tool to improve inventory management: a case study

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The main objective of this study consists on identifying those variables that influence the degree of success in implementing RFID technology, as well as its direct impact on inventory management.

The first stage of the analysis has consisted on reviewing the literature related to RFID in order to building up a framework. We have developed a longitudinal, in-depth case study of one Spanish firm who has dealt with the problem of implementing and using RFID technology. In this case study, we analyze all the stages related to the ex-ante implementation stage: background of the firm, origin of the project, objectives, and then, the different steps followed in the implementation. The case study is focused on the way in which the firm implemented RFID in their inventory and warehousing activities. We then show the qualitative and quantitative benefits it has obtained. We have used as informants the consultancy firm that managed the implementation, and all the managers and workers of the firm that were, first, involved in the implementation project, and, who later on, has used the technology.

We may advance some results about the variables that, in this case are crucial for a successful implementation and use of RFID technology. We have a set of variables referred to personal factors (the relationship between the firm and the consultants, the attitude of management and workers who had being using RFID in the firm). The second set of variables has being clustered in what we call technical factors (type of warehouse, the use of ERPs in the firm). Finally, we have a set of variables which are referred to supply chain integration, and the way in which customers have taken advantage of certain benefits provided by the implementation of RFID by this firm. We finish this paper comparing our variables with the framework that has emerged from the literature review.

Keywords: RFID; Case Study; Inventory management; Warehousing

Linking manufacturing flexibility to innovation performance in manufacturing plants

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In the past few decades, the concept of manufacturing flexibility has become a key competitive criterion for many manufacturing organizations. As such, there has been a plethora of studies on various aspects of flexibility including flexibility taxonomies (Slack, 1987; 1991; Koste and Malhotra, 1999; D'Souza and Williams, 2000), flexibility drivers, enablers and implementation (e.g. Suarez et al. 1996; Jack and Raturi, 2002; Oke, 2003, 2005) and measures of flexibility (e.g. Cox, 1992; Koste et al. 2004). The importance of flexibility in supporting other competitive criterion such as cost, quality, delivery speed and innovation has also been recognized (Bolwijn and Kumpe, 1990). For instance, it would appear that flexibility is fundamental to many of the new competitive frontiers including cost, innovation and speed. As Bolwijn and Kumpe (1990) argue, while a manufacturing plant can attain a flexible state without having to be innovative, the reverse is not true. In other words, flexibility is a necessary ingredient for innovation.

Our objective in this study is two-fold. First, we investigate the influence of generic enabling factors including supply chain effectiveness, process technology and information technology on flexibility in manufacturing plants. Second, we investigate the relationship between flexibility and a firm's competitive priorities with a particular focus on innovation performance. In these proposed relationships our focus is on mix flexibility – "the ability to change the range of products being made by the manufacturing system within a given period" (Slack, 1991; Oke, 2005). We investigate these relationships based on a survey of manufacturing plants in the UK. We discuss the results of the analysis and offer theoretical and practical insights emanating from the study.

Keywords: Mix flexibility, Innovation, Manufacturing

An optimal trade credit policy to increase supplier's profit when retailer's demand depends on inventory and storage capacity is limited

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There has been a lot of research papers appeared which deal with the inventory problems with varying conditions under trade credit intended to link marketing, financing as well as operations. The early papers assumed that the demand was a known constant. Hence, they ignored the effects of the credit period on the demand volume. In many actual situations, however, the supplier's intention of offering the trade credit period to retailers is to stimulate the demand for products. In order to reflect it in inventory models with trade credit period permitted, some researchers have employed price-sensitive, inventory-level-dependent demand et al. As we known, in practice, trade credit policy encourages the retailer to order large quantities because a delay of payments indirectly reduces inventory cost. In addition, for the system with inventory-level- dependent demand rate, holding large piles of goods will lead the customers to buy more. This will also make the system replenish more goods than can be stored in own warehouse. However, few inventory models with two warehouses have been found in the literature that addresses an inventory-level- dependent demand and trade credit policy. Furthermore, it mainly studies how the supplier sets the length of the trade credit period to maximize his/her own or the channel benefits. However, to the best of our knowledge, only limited papers have researched the above problem. Therefore, this paper tries to incorporate the retailer's inventory-dependent demand and storage space limited in the retailer's inventory model, which will make the decision-maker of inventory system to know whether to rent RW and how to order. Then, we focus on how the supplier designs the trade credit policy to maximize his/her own saving in operation cost. The proposed model shows that the trade credit policy can increase the overall chain profitability as well as each member's profitability, but is always more beneficial to the retailer than to the supplier at many situations. There is an interesting finding: offering the trade credit can sometimes have the channel profit under separate decision more than that in the centralized channel. It is contrary to the well-known result that the centralized system is always superior in performance to the decentralized system.

Keywords: Two-warehouse system, Inventory-dependent demand, Two-echelon channel, trade credit

INDEX

T

V

W

Y

Z