



2008 ISOM/ISE Workshop:
RFID & Supply Chain Information Management

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Sponsors:
SCALE Center (ISE Department)
Center for Supply Chain Management & DIS Forum (ISOM Department)

**Information Systems and Operations Management
& Industrial and Systems Engineering**
University of Florida
February 15-16, 2008

RFID & Supply Chain Information Management 2008 ISOM/ISE Workshop Program

Thursday, February 14, 2008

7pm – 9:30pm	Kick-off dinner	Han's
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Friday, February 15, 2008

Time	Event	Location
7:30am – 8:30am	Breakfast & welcome	UF Hilton
8:30am – 9:15am	Adam Mersereau (UNC): Information-Sensitive Replenishment when Inventory Records are Inaccurate	
9:15am – 10am	Gary M. Gaukler (Texas A&M): Item-Level RFID in the Retail Supply Chain: Product Availability and Demand Forecasting	
10am – 10:30am	Break	
10:30am – 11:15am	Benoit Montreuil (Laval): Item-Level RFID in Retail Facilities: Exploratory Investigation of its Value Creation Potential for Enabling the Real-Time Retail Demand and Supply Chain	
11:15am – 12:00pm	Manu Goyal (Maryland): Strategic Information Management under Leakage in a Supply Chain	
12:00pm – 1:30pm	Lunch	
1:30pm – 2:15pm	Metin Cakanyildirim (UT-Dallas): Partially Observed Inventories: Signals, Sufficient Statistics and Approximations	
2:15pm – 3pm	Jacques Roy (HEC-Montreal): Cost-Benefit Analysis of a Potential RFID Deployment in a Cruise Ship Supply Chain Context	
3pm – 3:30pm	Break	
3:30pm – 4:15pm	Tim Huh (Columbia): A Periodic-Review Inventory Model with Unobservable Demand	
7:00 pm – 9:30 pm	Reception	Tapas 12 West

Saturday, February 16, 2008

Time	Event	Location
8am – 9am	Breakfast	UF Hilton
9am – 9:45am	Diego Klabjan (Northwestern): Next Generation Business Applications for Radio Frequency Identification	
9:45 – 10:30am	Lawrence V. Snyder (Lehigh): Supply Disruptions and the Reverse Bullwhip Effect	
10:30 – 10:45am	Break	
10:45 – 11:30am	Sean Marston (Florida): The Impact of Digital Technologies on Government Cultural Policies	
11:30am – 12:00pm	Brown-Bag Lunch	

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Adam Mersereau (UNC)

Information-Sensitive Replenishment when Inventory Records are Inaccurate

The vast majority of inventory management research assumes that the inventory manager knows with certainty his inventory position. Recent empirical research, however, calls this assumption into question and reveals the reality of inventory management in practice: inventory records do not necessarily match the physical inventory on the shelf. Radio Frequency Identification (RFID) has been proposed as a solution to the problem of record inaccuracy. Instead, our interest is in intelligent inventory management tools that mitigate the costs of record inaccuracy, even without investment in RFID.

We study an inventory system with imperfect inventory records and unobserved lost sales. Record inaccuracies in our model are assumed to arise via an “invisible” demand process that perturbs physical inventory but is unobserved by the inventory manager. When inventory records are inaccurate, the true inventory level on the shelf is a random variable from the perspective of the inventory manager. We propose tracking inventory using a Bayesian Inventory Record (BIR), a probability distribution that evolves over time to reflect the inventory manager’s beliefs about the true inventory level, given replenishment and sales observations.

We formulate the problem of optimal BIR-based replenishment as a partially observed Markov decision process (POMDP). We analyze one- and two-period versions of the problem, isolating and interpreting impacts of record inaccuracy and invisible demand on the replenishment decision. In our setting, replenishment decisions in different time periods are coupled for two reasons: (1) because leftover inventory persists between periods, and (2) because replenishment decisions impact the shape of the BIR. The latter reason we call an “information effect,” and we find that it typically incentivizes a forward-looking inventory manager to stock less than he otherwise would. In this way, our research connects with known results on demand learning with censored observations, where an analogous information effect incentivizes an inventory manager to stock more.

We examine information-sensitive replenishments over longer horizons using an approximate POMDP algorithm inspired by the artificial intelligence literature. In numerical experiments, we find that our approximate POMDP algorithm achieves lower average cost than the myopic policy by ordering less. The approximate POMDP algorithm also achieves lower BIR standard deviations on average, suggesting that an information effect at least partially explains the difference between the myopic and forward-looking policies.

Gary Gaukler (Texas A&M)

Item-Level RFID in the Retail Supply Chain: Product Availability and Demand Forecasting

In this talk we characterize some of the operational benefits of item-level RFID in a retail environment. We examine a retail operation with backroom and shelf stock under the assumption of multiple replenishment and sales periods. Backroom stock is replenished according to a periodic-review order-up to policy and shelf stock is replenished continually from the backroom.

Replenishment decisions are made based on demand forecasts that are updated in each sales period based on previous sales. The influence of item-level RFID is two-fold: first, it directly affects the amount of products sold. Second, it indirectly affects the retailer's demand forecast: more products sold mean a higher demand forecast, which means a higher order-up to level in the backroom. We derive the optimal order-up to levels for backroom stocking for both the RFID and no-RFID cases, and we examine the relative magnitude of the direct (i.e., sales) and indirect (i.e., forecast-driven order-up to levels) effects on expected retailer profit. A numerical study of the dynamics of this system reveals several insights that are of managerial interest.

Benoit Montreuil (Laval)

Item-Level RFID in Retail Facilities: Exploratory Investigation of its Value Creation Potential for Enabling the Real-Time Retail Demand and Supply Chain

In this paper we focus on retail demand and supply chains exploiting RFID enabled retail facilities. Currently, in retail facilities RFID implementation is mostly limited to either back store portals for case identification. Some rare implementations are geared for item level identification, such as Gillette’s smart shelves for its disposable razors. As technology progresses and costs diminish, there will be ever more potential for large scale deployment of item-level RFID in retail outlets. Furthermore, as triangulation capabilities expand, such RFID implementations will gradually enable real-time three-dimensional positioning of tagged items through retail facilities. As technology progresses, the potential for real-time management of retail facilities exploiting RFID generated live positional information. Yet the adoption of these technologies will depend strongly on the value generated through the retail demand and supply chain, from the consumers to the manufacturers.

Our team has developed the LiveRetail experimental platform for enabling the experimentation of real-time management of RFID equipped retail facilities. It combines a retail facility configurator, an agent-based retail simulator and a web-connected real-time retail management cockpit.

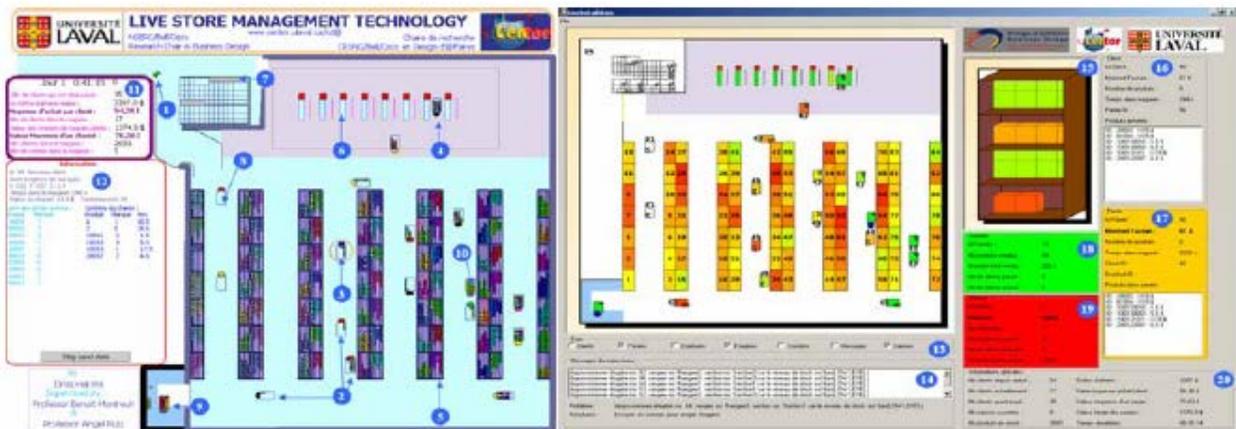


Figure 1. Screenshots from the LiveRetail platform

In the paper we first present the architecture and functionality of the LiveRetail platform. Second we then describe the key learnings from our early experimentation with the platform relative to value generation through the retail demand and supply chain. Third we extrapolate from our early findings so as to project the potential impact of item-level RFID on large retail networks, large consumer goods manufacturers, and consumers.

[Joint work with Angel Ruiz and Driss Hakimi]

Manu Goyal (Maryland)

Strategic Information Management under Leakage in a Supply Chain

The importance of material flow management for a profit-maximizing firm has been well-articulated in the supply chain literature. We demonstrate in our analytical model that a firm must also actively manage information flows within the supply chain, which translates to controlling what it knows, as well as what its competitors and suppliers know.

Our model of a supply chain consists of two horizontally competing firms sourcing from the same supplier. One firm (the 'incumbent') takes a lead in introducing a new product in the market, the demand for which is uncertain. The incumbent can invest in obtaining demand information not directly accessible to its competition. The second firm (the 'entrant') follows the incumbent in the market with the same or a perfectly substitutable product. Both firms source a component of the product from the (common) supplier. Now, if the incumbent has acquired information, his order to the supplier is likely to reflect some of that information. The supplier in turn could leak the incumbent's order information to the entrant. This structure in its barest form captures the essence of numerous examples of supplier-driven leakage, highlighted as a leading supply chain risk in multiple surveys.

We formally show that the supplier always leaks the incumbent's order information to the entrant. As a result, when the incumbent acquires information, its drive to control information flows within the supply chain can trigger operational losses through material flow distortion. Hence the firm may prefer not to acquire information even when it is costless to do so. However, if acquired, demand information is always disseminated in the supply chain, aided by leakage. This result is in stark contrast to the extant literature which argues that demand information is not shared in similar settings. Thus, in equilibrium, information asymmetry is dissipated in the supply chain - either all firms are privy to demand information or none are. Our results underscore the importance of Strategic Information Management - actively managing the supply chain's information flows, and making trade-offs with material flows where appropriate, in order to maximize profits.

[Joint work with Krishnan S. Anand]

Metin Cakanyildirim (University of Texas at Dallas)

Partially Observed Inventories: Signals, Sufficient Statistics and Approximations

In many inventory control contexts, inventory levels are only partially (i.e., not fully) observed. We discuss the recent developments in the partially observed inventory systems and the associated models. In these models, the inventory level or the customer demand is observed via surrogates (signals). The system state turns out to be the conditional distribution of the inventory/demand given a history of these signals. In some models, this history can be summarized by several statistics called sufficient statistics. For example, the information delay and some censored demand models accept sufficient statistics. When no sufficient statistic exists, we are forced to approximate the conditional distribution.

An option is to approximate the conditional distribution with its mean and variance. This methodology is applied to the zero-balance walk model where the demand is not observed, the inventory level is noticed when it reaches zero, the unmet demand is lost, and replenishment orders are decided so as to minimize the total discounted costs over an infinite horizon. This problem has an infinite-dimensional state space, which makes it difficult to obtain a simple optimal policy. We compare approximations that are based on the mean/variance or just the mean of the inventory level. The mean based approximation has the customary dynamic programming equation of the fully observed problem, while the mean/variance based approximation has a novel equation that resembles a mixture of equations of the fully and partially observed problems. Value functions of both the mean/variance based policy and the mean based policy can be used to obtain lower bounds for the actual cost, but the bound obtained from the former policy is stronger. Moreover, the former policy coincides with the latter policy when the variance of the inventory level is zero. Hence, the mean/variance based policy generalizes the policy of the fully observed problem.

Another option is to solve the actual problem by using numerical methods (such as a finite family of polynomials) to represent the conditional distribution. We report a preliminary comparison of the mean/variance based policy and the numerical solutions.

Our methodologies can be used to evaluate the benefit of technologies, such as RFID tags, from the inventory management point of view. These technologies provide richer, real-time information to inventory managers in the form of more accurate measures of inventory or more signals. In a sense, they make a partially observed problem more of a “fully observed problem”. The difference between the optimal cost of the partially observed problem and that of the fully observed problem is (a bound on) the benefit of the technology. This benefit can be used to make an objective case against or for the technology. The objectivity here is critical for companies hesitantly considering new technology implementations like RFID tags.

[Joint work with Alain Bensoussan, Suresh Sethi]

Jacques Roy (HEC Montréal)

Cost-Benefit Analysis of a Potential RFID Deployment in a Cruise Ship Supply Chain Context

It is understood that technology can bring great improvements to the supply chain. The latest technology to be promising new efficiencies is RFID. While the possibilities this technology brings seem to be clear to most, the efficiency gain remains vague. This study looks at the global supply chain operations of a large cruise ship company and measures the potential efficiency gains resulting from the application of RFID in three scenarios. Scenario 1 (S1) is a pallet level RFID tagging for pallets from the cruise company logistics center to the ships and case level tagging for express items from the logistics center to the ships. Scenario 2 (S2) is the application of pallet level RFID tagging across the supply chain involving all major suppliers, as well as the logistics center using RFID for pallet identification. Finally, scenario 3 (S3) considers case level for everything from suppliers to the logistics center and directly to the ships. For each of these scenarios we consider two possibilities for the cost of deployment: 1) that the cruise company bears the entire tagging cost or 2) that the cost of tags is shared with the suppliers. To establish the feasibility of these scenarios, a cost benefit analysis of the RFID application was conducted using a time study of current processes. Only direct benefits such as labour reduction and reduction in material resources were considered for this study; intangible benefits such as visibility and coordination improvements were not assigned a dollar value.

It was found that RFID tags in themselves can easily generate sufficient benefits to pay for the tags cost. However, cost amortization for the infrastructure to support RFID tag usage for components such as antennas and handheld scanners is considerable. In this context, the results show that using RFID technology can only generate substantial direct net benefits when two or more actors in the supply chain share the costs and benefits of a case level tagging deployment. However, for other scenarios to gain approval, the cost of the technology must further come down in order to generate an acceptable return on investment. Lastly, it was found that the key for a positive return on investment is not the scale of operations but the products flow density within the supply chain. The main contribution of this research is the examination of the application of technology and RFID in a global service supply chain. For practitioners, it provides a fresh look at RFID and technology costs and benefits.

[Joint work with Simon Véronneau]

Tim Huh (Columbia)

A Periodic-Review Inventory Model with Unobservable Demand

We consider a single-product periodic-review inventory system. In each period, we assume that the system faces two types of uncertain demand, recorded and unrecorded; the *recorded* demand refers to the paying customers whose transactions are updated in the system whereas the *unrecorded* demand refers to the reduction of inventory without being updated in the system, either due to information system incapability (unrecorded sales) or pilferage (loss). Any demand that cannot be satisfied immediately upon arrival is lost, and incurs a corresponding lost sales penalty cost. Due to the presence of unrecorded demand, the actual and the recorded inventory levels may disagree, but the managerial decisions, such as inventory counting and replenishment, must be made solely on the recorded inventory level. In our model, we assume that whenever inventory stocks out, the manager incurs a fixed penalty cost, and becomes informed of the stock-out event. Furthermore, we assume that inventory counting is costly, but is necessarily performed as a part of the inventory replenishment process.

While the actual inventory level at a given period depends on the entire history of the observed process (inventory records), we identify that sufficient information is captured by the pair of (i) the recorded inventory level and (ii) the number of periods since the last inventory correction. Under mild technical conditions, we obtain several monotonicity structural results, relating the actual inventory level and the recorded inventory levels, which are useful developing the structure of the optimal policy. If the unrecorded demand consists of unrecorded sales and the inventory cost is charged based on the maximum storage capacity, then we show the optimality of a two-parameter policy, called the (l, S) policy. If unrecorded demand is either unrecorded sales or loss and the inventory cost is charged based on the actual inventory level in each period, then we identify a sufficient condition for the optimality of (l, S) policy, which is shown to be optimal in our numerical experiments.



Diego Klabjan (Northwestern)

Next Generation Business Applications for Radio Frequency Identification

RFID is moving from early stages of slap-and-ship to integration with existing systems and business applications. It is the latter that will yield a return on investment. In addition to existing business applications such as promotions execution we discuss in details two new novel applications.

We present new models that capture real-time status of shipments and make optimal inventory control decisions. In addition, we show analytically that RFID real-time data yield better inventory control policies than the traditional setting. RFID data can also be explored in expediting replenishment orders. We introduce so-called sequential systems, which have nicely structured policies. The regular and expediting orders follow a base stock type policy.

Lawrence V. Snyder (Lehigh University)

Supply Disruptions and the Reverse Bullwhip Effect

Hurricane Katrina in 2005 crippled much of the U.S. oil drilling and refining capacity, and as a result, demand for gasoline nationwide was very volatile in the days and weeks following the storm. On the other hand, production was quite stable, since drillers and refiners were operating at their (newly reduced) capacity. This is the opposite of the classical bullwhip effect (BWE), in which demand/order volatility increases as one moves upstream in the supply chain. We postulate the existence of a “reverse bullwhip effect” (RBWE) that occurs during and immediately after supply disruptions.

We introduce two analytical models to demonstrate the existence of the RBWE. In the first, we assume that a single buyer procures product from a single seller that is subject to disruptions in the form of capacity shocks. A change in capacity causes a change in the price of the product. If the buyer anticipates further price changes in the future due to a prolonged disruption, he may purchase a quantity that differs from the quantity specified by his steady-state demand curve. We provide conditions under which the variance of (an approximation of) the order quantity exceeds the variance of the capacity, and therefore that the RBWE occurs. We also prove that the magnitude of the RBWE increases with either the severity or the duration of the disruption.

Our second model examines buying patterns when multiple retailers compete for scarce product from a single supplier. This model is based on the “rationing game” discussed by Lee, et al. (1997), who argue that the BWE occurs between the retailers and their customers (i.e. the retailers’ orders are more volatile than their customers’ demands). We examine this claim more closely, verifying it under certain conditions and questioning it under others. Furthermore, we argue that the capacity uncertainty causes the RBWE to occur in the upstream portion of the supply chain; that is, that the retailers’ orders are more volatile than the supplier’s orders. Finally, we consider an alternate pricing structure in which the retailers pay for every unit ordered, plus a separate price for units actually received. This pricing structure discourages retailers from inflating their orders too severely. We demonstrate that this pricing structure causes a Nash equilibrium of order quantities to exist where it otherwise would not, and we prove the resulting existence of the (R)BWE.

[Joint work with Zuo-Jun Max Shen, Ying Rong]

Sean Marston (Florida)

The Impact of Digital Technologies on Government Cultural Policies

Many countries limit the influence of foreign cultural products such as music, film, and television programs to protect their cultural identity. Commonly observed tools include Quotas, tariffs, and subsidies. However, the advances in digital technology create new avenues, such as internet, for consumers to access foreign entertainment programs. This calls a re-examination of the effectiveness of these traditional tools. We create a unified analytical framework to study the impact of digital technology on cultural protection policies. We find that the performances of these tools are greatly affected by the quality difference between domestic and foreign entertainment programs (through both traditional channel and Internet), and quota produces the least social welfare no matter whether there is leakage through internet.

[Joint work with Kenny Cheng, Jane Feng, Gary Koehler]