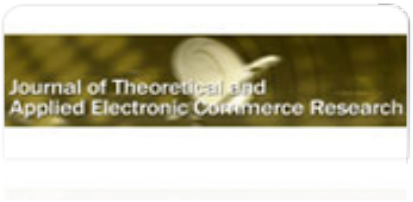

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Guest Editors' Introduction

RFID and Supply Chain Management: Introduction to the Special Issue

As markets become more global and competition intensifies, firms are beginning to realize that competition is not exclusively a firm versus firm domain but a supply chain against supply chain phenomenon. Visibility across operational activities—from demand forecasting, to the sourcing of raw materials, through to manufacture and dispatch—is critical to supply chain competition. Customers will no longer tolerate delays in response times and information is required in minutes not hours, to enable individual stakeholders to plan, organize and control their supply chain activities. Consequently, the most effective supply chain networks are dynamic in nature, distributed in architecture and leverage sophisticated real-time analytics.

Information technology has a key role to play in supporting supply chain competition. The critical question for executives—and the focus of this special issue—is how to leverage emerging information technologies, such as radio frequency identification (RFID) to support supply chain operations? As an electronic identification technique, RFID offers a potential solution to the item/object transparency problems that have plagued supply chains in the past. For example, RFID technology can be used to: (1) reduce the time taken to reorder shipments, (2) reduce product shrinkage and theft, (3) improved tracking of pallets, cases and individual products, and (4) provide better planning and optimization of inventory and reusable assets.

While bar codes offered significant advantages to organizations in terms of automatic data capture they were mainly instituted to identify goods for the purpose of gathering historical data. Bar codes are based on write once read many technology. In contrast, RFID passive tags (no internal battery) and active tags (self-powered battery) are updatable, enabling the transmission of data without a physical connection or line of sight. The non-line of sight capability of RFID makes it a perfect supply chain technology [12]. Passive tags operating under the ultra high frequency (UHF) band are common to supply chain applications because tag costs are low and the read range and rate is adequate [14]. In the case of supply chain management (SCM), RFID is not just about the identification of an individual pallet, case or item but about the relationships between objects, between organizations, between space and time. RFID is about process level change that can streamline business-to-business (B2B) operations and bring about major changes to organizational policies, culture, performance and structure [10].

Item relationships and the complex information flows required to manage objects in modern supply chains are increasingly being formalized through the efforts of EPCglobal (Electronic Product Code™) standards [9]. The EPC provides a static ID which is stored in the RFID tag, providing a simple extension to the Universal Product Code (UPC), which bar code technology is based on. These standards allow organizations to move faster, provide richer information sources and increase the efficiency of trading networks. From a purely technical standpoint, RFID offers potential advantages not just across the supply chain but in an organization's warehouse where discrepancies are said to occur before the error is propagated to partnering suppliers and customers. RFID for location positioning of inventory on the warehouse floor, in addition to RFID coupled with the use of sensors to support exception handling pertaining to predetermined levels of temperature, pressure, humidity, distance or depth is likely to save organizations considerable money, not to mention partners' precious time as a result of the minimization of errors.

However, much of the sensationalism synonymous with RFID has worn off. Larger retail players like WalMart and Target have re-evaluated their mandate for all of their suppliers to use RFID technology. Technical challenges such as erroneous reads, read collisions and the costs of handling large amounts of data generated by RFID have hampered progress. The technology is no longer touted as an ideal item-level labeler, and RFID is unlikely to make bar codes obsolete or make persons at the checkout redundant, at least for now. In hindsight, it was naïve to think that sanguine commentary regarding the benefits of RFID would negate business reality. The reality is that the process level change demanded by RFID still requires endless hours of discussion with organizational stakeholders at various levels; strategic, tactical and operational [8]. The technology is still not well understood outside the laboratories, tag orientation requires extensive trials, and companies are still not willing to part with scarce resources for capital intensive projects and concerns over the invasion of privacy. Indeed it was privacy concerns that initially hampered the first major RFID retail trials in the United States [6].

A complete RFID system comes at a considerable cost given the requirements for tags, readers, antennas, software, and a computer network used to connect the readers. This represents a major outlay for any business and one of the major issues at the present time—due to a lack of institutional knowledge in the RFID space—is that vendors are not always selling systems that meet business requirements fully. The know-how of "putting it altogether" to provide an end-to-end functional system is an important obstacle that should not be underestimated, especially if one is considering integration with current large-scale enterprise resource planning (ERP) software systems like SAP.

Middleware software is also critical to the effective operation of RFID in the supply chain. RFID Middleware research received a significant impetus with the Walmart mandates that went into effect in 2005. The first middleware

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architectures were based on supporting EPC as a UPC bar code replacement. This basic EPC technology was able to provide individual IDs to items (e.g., toothbrush, printer cartridge) enabling the complete inventory of a retailer to be tracked. Potentially, huge amounts of data can be created, routed, stored and managed in a RFID enabled supply chain. The need for scalability therefore motivated the requirement for an extra layer of software – or the RFID Middleware with the WinRFID middleware at UCLA being a typical example of such an endeavor [5].

Managing scalability is a key concern to enterprises and their CIOs with responsibility for the deployment of RFID systems. Furthermore, the large amount of RFID data that is generated from the movement of physical goods in a real world setting is rarely clean, the data is often noisy, has errors and is sometimes unusable in its native form. This situation motivates the need for an intelligent component within the RFID that filters, aggregates, sorts and adds intelligence to the RFID data [13]. This capability is something a state of the art middleware must have to ensure the raw RFID data is usable, making the job of the CIO easier. Outside of a lab environment, the scalability of RFID systems has yet to be truly tested as we are in the infancy stages of the actual deployment of RFID in the real world.

The world has now moved far beyond the original notion of the tag as a static EPC—the RFID tags of today contain much more memory. Standards-based ISO tags such as those operating at the high frequency or HF range can now provide for up to 8 Kilobits of memory. For example, the announcement by Hewlett Packard (HP) of its memory Spot technology provides for an RFID chip containing 4 Megabits of storage that can be written to and read multiple times [7]. Active or battery assisted tags are now able to store even large amounts of data with much higher data download and upload speeds. Sensor tags that measure temperature, humidity, pressure, vibrations, NOX/Sox etc., are becoming increasingly available and dropping in price. Therefore the RFID arena has greatly expanded, with equal strains being applied to the traditional RFID model. Middleware architectures need to support multiple standards such as ISO, EPC, etc., support multiple protocols, data protocols, memory sizes, etc., all within a single architecture – something the WinRFID initiative has proposed from the outset. Previous research has shown that such architectures are plausible and also scalable [17]. Future research in middleware needs to expand such architectures to make them secure and easy to integrate into enterprise IT infrastructure and develop services around them [16].

The eventual success of a middleware is in its ability to deliver a useful enterprise software application. From a business strategy perspective, RFID (barring mandates) exposes many unanswered questions:

- Is there a business case for RFID and how does one calculate the return on investment (ROI)?
- Can the cost per RFID tag reach feasible economies of scale for individual level tagging?
- Can RFID provide the same kind of accuracy as its predecessor the bar code?
- Who will bear the costs of deployment in the supply chain and how will these costs be distributed in an equitable manner?
- Should different business sectors and business sizes become involved and if so, when and how?

Early adopters have found it difficult to generate measurable returns from RFID adoption. A key reason for this is that RFID is essentially infrastructure technology or what economists call general-purpose technology [3, 4]. To maximize competitive advantage in a supply chain context, RFID needs to be used by multiple companies to do all sorts of things, creating widespread advantages for all supply chain participants. Because of its broad application RFID requires considerable economies of scale. But the new forms of RFID technology being introduced with different RF physics, transmission schemes, different frequency bands, new protocols, new standards and changing government regulations will take considerable time for economies of scale to be appreciated. By necessity, RFID is still in a fragmented state and adoption of RFID is still contained to specific application areas where the highest returns exist.

The empirical evidence based on prior technological advances that are similar to RFID indicates that being the first to adopt RFID is not necessarily advantageous [2]. Early adopters often miss the best opportunities by failing to: (1) develop the right strategic applications and resources, (2) leverage the scale advantages that are necessary, (3) commit the necessary resources to ensure equitable allocation of costs, and (4) get the technology right the first go. In other words, most IT-based pioneering efforts have proven to be poorly directed, leaving opportunities for others to capitalize on the learning and opportunity [11].

At this stage, RFID technology is best suited to contained areas in vertical markets. Even though initially the buzz was around retail, today a host of other industries have made strides in using RFID and RFID middleware to develop applications. For example, the airline industry has successfully used RFID to improve baggage handling and link bags to persons and flights. In the pharmaceutical industry there is an increasing need to ensure the traceability of drugs throughout the supply chain. Hospital nurses are frequently riddled with tasks such as note taking and inventory matters that distract them from their patient care responsibilities. Some sectors such as healthcare have had remarkable early success with applications that are closed loop (as opposed to supply chain that is open loop) that track assets, specimens, patients, blood, etc. Lastly, RFID is likely to succeed sooner rather than later in the

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context of very large supply chains such as the United States Department of Defense (DoD). Since 2005, 97% of the DoD's pallets bound for Iraq have been shipped with RFID tags [1], [15].

Against this background, this Special Issue of the Journal of Theoretical and Applied Electronic Commerce Research is a culmination of the collaborative efforts by several authors and reviewers aimed at providing a synthesis of current thinking and leading-edge research in RFID and Supply Chain Management. The nine papers comprising the Special Issue have undergone a rigorous review process and were deemed to make a substantial contribution to the field of RFID in the Supply Chain context. Four of the papers are strategy related, three use simulation methodology, while the remaining two provide application case studies. The call for papers attracted full submissions from no fewer than eleven countries around the world, thus lending a truly international flavor to this Special Issue. The international diversity in submissions covering almost every continent in the world indicates that RFID not only has global appeal but will diffuse widely when the market matures. It is with confidence that we state that the accepted papers offer truly new insights into RFID and SCM and we thank the authors and reviewers for their contribution to the field. A brief summary of each paper follows:

Three contributions use simulation methodology to illustrate the potential impact of RFID. D'Mello, Matthews, McCauley and Markham studied the characteristics of four commercially available RFID tags. Their aim was to evaluate the impact of position and orientation of RFID tags on simulated real time asset tracking in the supply chain. This type of fine grained, empirical testing of RFID tag location offers valuable insight into the obstacles that confront firms seeking to implement RFID in the supply chain. Bottani reproduces an end-to-end fast moving consumer goods warehouse to illustrate the potential benefits of RFID technology. The results from the discrete event simulation are analyzed to show how EPC data can be usefully exploited for real time monitoring and optimization of warehouse processes. This paper has strong practical implications for RFID in supply chain management. Munoz and Clements extend upon popular beer game simulation work to show how disruptions in information flows can affect the performance of manufacturing supply chains. Using a unique simulation they quantify lost sales revenue attributable to information and material delays. This work provides a novel approach to justify the adoption of new technology such as RFID in the supply chain.

Jeong and Lu examine the impact of RFID investment announcements on the market valuation of the firms over a six-year period from 2001 to 2006. The results provide managers with a clearer understanding of the benefits from RFID investment. Veeramani, Tang and Gutierrez offer a detailed framework for assessing the value of RFID on tier one suppliers. This type of analysis is critical to the future progress and development of RFID in supply chain management. Winjgaert, Versendaal and Matla provide a business/IT alignment (BITA) framework for RFID in logistics observing the phenomenon that organizations are usually more willing to invest in business/IT areas that are already well developed than in new technologies such as RFID. The study is comprised of thirteen case studies and the results indicate that besides business/IT alignment there are other factors that influence the choice of new technology adoption. Soon and Gutierrez provide a chronological overview of the impact of RFID mandates on suppliers. Their paper is particularly useful to managers and researchers seeking to develop a deeper understanding of the business justification for RFID. Various trends and patterns are identified for two groups of suppliers: suppliers directly affected by mandates and suppliers adopting a wait-and-see tactic.

Two RFID application papers are also presented. Wamba and Boeck focus on presenting a case study of a retail supply chain. The case illustrates how end-to-end information flows between supply chain members can be improved with new technology such as RFID. Zhang, Ouyang and He show how RIFD is used to support baggage handling in a major international airport in Beijing. Baggage handling has been a major application area for RFID and the paper presents data on read rate accuracy and cost savings.

Lastly, we wish to take this opportunity to thank all authors who submitted their excellent manuscripts to the call for papers on RFID and Supply Chain Management. To all the reviewers we thank you for your many constructive comments and suggestions. We are extremely grateful to the Editor-in-Chief of JTAER, Narcisco Cerpa, for giving us the opportunity to put together this Special Issue and believe that by placing RFID into a modern supply chain landscape we have produced a Special Issue that is valuable and informative.

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