EMPIRICAL EVIDENCE OF RFID IMPACTS ON SUPPLY CHAIN PERFORMANCE

John K. Visich, Bryant University, Smithfield, RI, jvisich@bryant.edu, 401-232-6437
Suhong Li, Bryant University, Smithfield, RI, sli@bryant.edu, 401-232-6503
Basheer M. Khumawala, University of Houston, Houston, TX, bkhumawala@uh.edu, 713-743-4721
Pedro M. Reyes, Baylor University, Waco, TX, pedro_reyes@baylor.edu, 254-710-7804

ABSTRACT

The purpose of this paper is to investigate the actual benefits of radio frequency identification (RFID) on supply chain performance through the empirical evidence obtained from the earlier adopters of RFID technology. For retailers, RFID can reduce stockouts, improve inventory accuracy, increase sales and speed up goods receipt. Benefits for logistics providers include improvements in receiving, shipping and inventory control processes and various yard management activities. Manufacturers have used RFID to design more efficient production systems, increase capacity, decrease lead time, curtail theft and reduce tool expenditure. Forward and closed-loop supply chains have also benefited from RFID implementations.
Key Words: radio frequency identification, RFID, auto-ID, supply chain, empirical results

INTRODUCTION

Radio Frequency Identification Technology (RFID) has received increased attentions from practitioners and academicians. The origins of RFID technology can be traced back to laboratory research in the 1940s that focused on reflected power communication. Commercial use began in the 1980s, primarily in the transportation industries of railroad and trucking [54]. These applications used battery powered active RFID tags and proprietary systems to track and manage capital assets, such as rail cars and cargo ship containers [31]. The expansion of RFID into the supply chain has been due to the reduction in the cost of RFID technology through the use of passive tags which do not contain a battery [123]. Passive tags are powered by the electromagnetic waves sent out by the reader.

Due to the mandates from Wal-Mart [70] and the United States (U.S.) Department of Defense [24], January 2005 can be considered the 'big bang' for radio frequency identification (RFID) technology. Other early adopters of RFID technology include Target [65] and Metro Group [26], the world's second and third largest retailers, The Gap, Woolworth's, Allied Domecq, Argos, and Tesco [126]. In addition, the U.S. Food and Drug Administration (FDA) has strongly recommended that the pharmaceutical and health care industries adopt RFID as a way to prevent counterfeiting and the injection of poisonous drugs by terrorists into the drug supply chain [37]. Wal-Marts' objective was to replace bar codes and scanners with RFID tags and readers in order to increase speed, efficiency and security in the supply chain [120], and to reduce inventory, out of stock merchandise, and labor cost in stores and warehouses [98]. Other proposed supply chain performance benefits included: improved accuracy and security of information sharing across the supply chain [47]; reduced storage, handling and distribution expenses; increased sales through reduced stock outs; improved cash flow through increased inventory turns and improved utilization of assets [49]; improved customer service and satisfaction; and increased collaboration and planning [58]. Due to these reputed benefits and the quantitative estimates of

benefits provided in numerous consulting and solution provider white papers, companies began showing an increased interest in deploying RFID systems.

However, the benefits and issues concerning RFID lead to confusion concerning the actual state of RFID. For example, an August, 2005 survey by *Computerworld* found that RFID was the number 1 technology that did not live up to its promise in 2005. Yet, in the same survey, respondents ranked RFID as the number 2 technology that held the most promise in their industry or company [119]. The annual "Global Survey of Supply Chain Progress" administered by Computer Sciences Corp. and *Supply Chain Management Review* found almost no mention of RFID in the 2004 survey. Yet, in the 2005 survey, more than 80% of respondents reported they had begun to develop internal RFID capabilities, 16% reported using RFID to advance the supply chain and drive results (12th out of 14 technologies), and 30% planned to invest in RFID over the next 3 years. The survey also noted the high priority respondents gave to developing the business case for RFID [84]. In the 2006 survey, 37% of the respondents planned to invest in RFID over the next 3 years [85].

But, these benefits of RFID implementation are not achieved immediately and there are a number of issues impeding RFID adoption. An April, 2004 survey of 80 companies by Accenture found that barriers to RFID implementation included: the cost of tags, readers and implementation; a lack of standards; market instability; complexity of integration with existing systems; and data synchronization [1]. A December 2004 survey by *Logistics Management* of companies involved in Wal-Mart's RFID mandate found that the number one concern of the 93 respondents was a lack of ROI (42.3%). Other top concerns were cost (23.1%), no benefit to us (11.5%) and lack of support from Wal-Mart (7.7%) [33]. Other early implementation issues include: wild fluctuations in tag reads; consumer privacy concerns [105]; environmental impact [67]; and security [59].

The Bain 2005 Management Tool survey of 960 global companies ranked 25 management tools on a scale of 1 to 5 with 5 as the best. The survey found that RFID was last in usage with only 13% of respondents reporting the use of RFID and ranked 12th in satisfaction with an average score of 3.89. Yet, in cases where a tool had been implemented as part of a major organizational effort, RFID ranked first with an average score of 4.43 [90]. In the Bain 2007 Management Tool Survey RFID was again last in usage with only 23% of respondents reporting the use of RFID and ranked 24th in satisfaction with an average score of 3.55. In cases where a tool had been implemented as part of a major organizational effort, RFID again ranked first with an average score of 4.34 [91].

Compounding the confusion concerning RFID is the lack of information on RFID implementations. In January, 2007 Wal-Mart had 600 mandated suppliers tagging cases and pallets [107] being sent to 5 distribution center and 1000 stores [63]. Yet, with all these suppliers deploying RFID, there is a the lack of information concerning the quantitative results of those RFID deployments. Moore [66] reported that RFID vendors and systems integrators have signed non-disclosure agreements, thereby preventing them from discussing RFID implementations. In our opinion, this wall of silence regarding empirical evidence of RFID has created a black hole around RFID technology. This lack of information has had a duel effect, fueling speculation that RFID is a failing technology and allowing exaggerated estimates of benefits to go unverified.

In order to mitigate unrealistic expectations and false perceptions of RFID technology due to published hype, [40] identified 10 popular RFID myths (both positive and negative). For each myth discussed they presented the current reality of RFID. They concluded their paper by

stating "Separating myth from reality should help provide rational expectations and perceptions so that organizations, consumers, and governments have a more realistic understanding of RFID" (p. 14). Lee and Ozer [57] reviewed the exaggerated estimates of RFID benefits that were reported by numerous consulting companies and solution providers. They concluded "there exists a credibility gap in all these reports, and in extreme cases, they amount to hypes" (p. 41). From the above discussion it is clear there is confusion concerning the benefits of RFID technology. In this paper we present the results of an extensive literature survey of practitioner focused articles and academic journal papers to identify empirical examples of RFID on supply chain performance. In addition, we discuss the managerial and academic implications of implementing RFID in the supply chain, provide implementation advice for practitioners and suggestions for further research on RFID systems.

EMPIRICAL EVIDENCE OF RFID

In our review of the empirical evidence of RFID in the supply chain we report only on those metrics that are based on actual results from a pilot study or implementation. We do not include: estimated benefits; benefits that have been masked to protect confidentiality [60]; results from unidentified companies (unless the results are significant); and aggregated evidence from multi-year implementations across all of a company's facilities [20] [21]. We present the empirical evidence of supply chain performance improvements due to RFID using the categories retailers, distributors/logistics providers, manufacturers/suppliers and the supply chain as a whole.

Retailers

We have previously noted that reducing inventory and out-of-stock merchandise were two objectives of Wal-Mart's RFID initiative [98]. According to Wal-Mart CEO Lee Scott, "we see RFID - anything that really allows you to reduce inventory while increasing on-shelf availability - as something worth pursuing" [31, p. 13]. Wal-Mart holds approximately 20 billion U.S. dollars in inventory and has an annual inventory turnover of 6, and increasing inventory turns from 6 to 12 could free up 12 to 14 billion U.S. dollars in cash [31]. An analysis of out-of-stocks by Corsten and Gruen[32] found that that average out-of-stock rate for 40 studies was 8.3% and that 75% of the responsibility rests at the store level. RFID applications at the retail level have reduced stockouts, improved inventory accuracy, increased sales, and speed up the goods receipt process. See Table 1 for a summary of empirical evidence of RFID in the retail store.

TABLE 1 Empirical Evidence Of RFID In Retail Store

Processes	Empirical Evidence	References
Receiving	Pallet breakdown: decreased from 17.75 minutes to 2.7 minutes	[73]
Backroom Inventory Management	Understated perpetual inventory (PI): 13% reduction	[41]
	Overstated PI: 50% reduction	[8]
	Time for inventory count: 80% reduction	[95]
	Inventory count accuracy: 98.4% or 99.6%	[28] [76]
	Inventory replenishment: 3 times faster	[106]
	Manual inventory orders: 10% or 42% reduction	[106] [75]
	Products locating accuracy: 99.9%	[108]
Store Floor	Stock-outs: 21%, 25% or 26% reduction	[42] [76] [77]
	Shelf-availability: increased to 100%	[125]

Promotions and Sales	Promotion product availability: 92% by day 3 of the promotion launch	[29]
	Promotion sales: 48%, 61% or 140% increase for stores moved the display to their location before the promotion	[8] [94] [92]
	Units sold: 14% or 41.1% increase	[72] [45] [9]
	Sales: 14%, 18.7%, or 30% increase	[45] [9] [109]

Logistics Providers

Benefits of RFID for logistics providers have been identified for a variety of warehouse and transportation processes and activities. In Table 2 we present a summary of empirical evidence of RFID in logistics processes including receiving, shipping and inventory control, as well as for various yard management activities.

TABLE 2 Empirical Evidence Of RFID In Warehouse And Distribution Centers

Processes	Empirical Evidence	References
Receiving	Arrival inspection time: reduced from 10% to 50%	[44]
	Check in and truck unload: reduced by 15 to 20 minutes	[17]
	Order verification: reduced from 20 seconds to 5 seconds	[51]
	Productivity for receiving goods: 57%	[11]
	Time needed to compare deliveries with orders: 80% reduction	[121]
	Time to process a delivered pallet: reduced 51%	[73]
Shipping	Time to process an order for shipment: reduced from 45 minutes to 6 minutes, or reduced to 20 seconds compared with 80 seconds to 20 minutes for a bar code system, or reduced by 80%	[99] [78] [51] [11]
	Pallet build speed: reduced from 90 to 11 seconds	[99]
	Time to load a truck: reduced from 50 minutes to 20 minutes, 40% faster	[110] [7]
	The accuracy of pallets shipping to customers: increased from 92% to 97%	[22]
	Invoice discrepancies: reduced from 80% to 0%	[27]
Inventory Management	Warehouse labor: 14% reduction	[17]
	Stock availability: 11% increase	[17]
	Lost goods: 18% reduction	[17]
	Inventory count accuracy: increased from 96% to 99%	[5]
	Stock turnaround: increased from 5.5 to 6	[78]
Yard Management	Time for double transaction (drop-off & pick-up): 66% reduction	[14]
	Parking spaces: save 40-60 at a given time	[14]
	Gate personnel productivity: improved 50%	[14]
	Daily throughput: 38% during peak season	[14]
	Reduced labor: 2 persons	[6]
	Reduced tractors: 120 to 67 per year	[6]
	Container locating: from 4 to 12 hours to immediately	[97]
	Gate efficiency: improved 75%	[79]

Manufacturers and Suppliers

While most of the recent discussion in the press has centered around supply chain applications, RFID has been used in a number of manufacturing applications for many years. According to Stall (1993) the automotive industry was one of the first manufacturing groups to use RFID technology to control and track products moving on assembly lines, and the reusable part bins that fed the line. Table 3 presents empirical evidence of RFID in the manufacturing environment.

TABLE 3 Empirical Evidence Of RFID In Manufacturing

Processes	Empirical Evidence	References
Production Planning	Production planning accuracy: improved 29%	[74]
Procurement	Procurement cost: reduced 11%	[117]
Production	Labor cost: reduced 17%	[117]
	Cycle time: reduced from 88 to 46 minutes	[25]
	Production capacity: increased 6.5%, 57%	[25] [79]
	Lead time: reduced 27%	[74]
	Packaging errors: eliminated	[12]

The Supply Chain as a Whole

It has been noted by numerous authors that the highest level of benefit from RFID will occur when RFID is implemented across multiple supply chain partners. In this section we present empirical evidence of RFID benefits for forward and closed-loop supply chains. See Table 4 for a summary of empirical evidence in forward supply chains and Table 5 for a summary of RFID in closed-loop supply chains

TABLE 4 Empirical Evidence Of RFID In Forward Supply Chain

Metrics	Empirical Evidence	References
Supply Chain Response Time	Supply chain response time: reduced from 7 to 5 days	[111]
	Inbound and outbound through-put time: reduced by 50%	[35]
	Handing time: reduced by 50%	[35]
	Delivery time: reduced from 28 to 16 days	[30]
Supply Chain Cost	Labor cost: reduced by 25%	[80]
	Inventory cost: reduced from $127 million to $70 million	[30]
	Product loss: 10% reduction	[112]
Supply Chain Efficiency	Number of goods processed: doubled or tripled	[81]
	Rush order processing: reduced from 6 hours to 2/3 hours	[81]
Integrated Supply Chain Benefits	Supply chain cost: reduced by 75%; Revenue: increased 10%; Capacity: increased up to 15%; Process lead time: reduced by 70%; Customer complaints: reduced 22%	[23]
	Average delivery time: reduced from 28 to 16 days; Supply backlog: reduced from 92,000 shipments to 11,000	[30]

TABLE 5 Empirical Evidence Of Rfid In Closed-Loop Supply Chain

Application	Empirical Evidence	References
Reusable Assets	Read time for reusable assets: reduced by 83%	[125]
	Shrinkage: reduced by 15%	[125]
	Container loss: reduced from 4% to 2%	[125]
	Container cycle time: reduced from 47 to 40 days	[6]
	Container purchasing cost: reduced by 4 million pounds per year.	[125]

RESEARCH IMPLICATIONS AND CONCLUSIONS

This research has positive implications for practitioners and academician. The data presented shows the impact of RFID expressed as quantitative values, not as estimates or as unclear statement such as 'improved inventory visibility' or 'sped up the receiving process'. Significant benefits have been reported for a variety of supply chain entities, processes and performance measures. For managers, the empirical evidence presented can help them identify implementation areas where RFID can have the greatest impact. The data can be used to build the business case for RFID and therefore better estimate ROI and the payback period. Academicians can use the data as modeling parameters for supply chain and manufacturing studies. However, it is concluded that the implementation of RFID is at the early stage and the majority of deploying companies have not fully obtained the estimated benefits reported in the literature.

Moeeni [64] noted that Moore's law favors RFID as the costs associated with implementing RFID systems has continuously declined while performance has improved. Moeeni also stated that according to Metcalfe's law, as more organizations deploy RFID the business value of RFID should increase. We agree with these assessments and our research has shown there is a business case to be made for RFID technology in the supply chain. However, it is up to each individual business to implement RFID technology in order to improve process efficiency and through business analytics identify revenue enhancing opportunities in the market.

This research has some limitations. First, the empirical evidence cited in this paper was collected from secondary sources and therefore not directly observed by the authors. This leads to the second limitation which is the lack of consistency in performance measure definitions. Finally, all articles reviewed were written in English. Given the significant level of RFID interest in Europe, Asian and Latin America we are sure to have missed empirical evidence published in a different language.

Future research on RFID implementations should focus on detailed case studies that investigate the impact of RFID on multiple processes across the organization and the supply chain. Research should also focus on cross-functional applications such as between operations and marketing, as well as how RFID can be used by accountants to help meet Sarbanes-Oxley requirements for supply chain activities.

Note: The complete paper with an extensive literature review, detailed discussions of the empirical evidence, and full references can be requested from the first author.