Radio Frequency Identification (RFID) Implementation Efforts at Four Firms: Integrating Lessons Learned and RFID-specific Survey

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1. Background

For more than a century, information technologies have revolutionized the way supply chain management control systems have been designed and implemented. Particular examples are the telegraph used for railroad transportation scheduling, the telephone (and facsimile) for faster business communication, bar codes for automatic data acquisition, and EDI for more efficient and paperless exchange of business transactions. While such technologies have enhanced the business practices of those eras, the benefit was limited to specific supply chain processes (and the integration thereof). Furthermore, there were no real solutions for evaluating the tradeoffs between cost, rich content of data, real-time information, and up- and downstream integration between all business partners (Frohlich and Westbrook, 2002).

Above all, the Internet has been known to address the limitations of pre-Internet business technologies and the tradeoffs previously mentioned. A wide variety of businesses are now redesigning their supply chains and using Internet-based tools for supporting their business processes (Cagliano et al., 2003). These Internet-based tools support procurement (Min and Galle, 1999; de Boer et al., 2002; Rahman, 2003; Chen et

al., 2004; Pagell, 2004), operations (Kehoe and Boughton, 2001), distribution (Lancioni et al., 2000; Rahman, 2003; Pagell, 2004), customer relationships (Cagliano et al., 2003), collaboration (Cagliano et al., 2003; Ovalle and Marquez, 2003), lean manufacturing systems (Bruun and Mefford, 2004; Yusuf et al., 2004), and the integration thereof (Ito and Salleh, 2000; Frohlich and Westbrook, 2002; Rahman, 2003; Lee et al., 2003; Power and Simon, 2004).

Since the introduction of the term "supply chain management" (SCM), it has received a growing interest in both the academic research literature and industry practice (Stradtler, 2005). In addition, information technology (IT) has had a substantial impact on SCM (Cachon and Fisher, 2000). Today's practitioners cannot "management speak" SCM without describing how IT can be used to manage it—further implying that it is difficult to academically research SCM designs without considering IT (Reyes, 2002; Reyes, 2006). Likewise, this growing interest in SCM questions "what is the best design for our supply chains?" seeking to further advance SCM research and practice. These changes in the SCM landscape are transforming the working structure and design of corporations.

Coupled with this SCM landscape transformation, managers are continuously seeking to improve supply chain operation practice and performance. A significant modern challenge is how to integrate emerging automatic data acquisition technologies, like radio frequency identification (RFID), into SCM practice in order to improve performance.

RFID, not a new technology, however is being celebrated as a significant improvement over the conventional technology, which promises to close the information

gaps in supply chain integration. When compared to the conventional approaches, such as barcode or manual data entry, RFID enables more efficient automatic data acquisition, data identification, and information exchange among supply chain members for tracking product, sorting, and distribution data collection and analysis (Hou, J-L. and Hung, C-H., 2006; Prater et al., 2005; Smith, 2005, Reyes and Frazier, 2007).

RFID is in a family of technologies that can be used for automated data collection, which Gupta (2000) points out, could be used to augment ERP systems. In addition, this technology can also facilitate inter-organizational e-commerce initiatives, such as continuous replenishment or vendor-managed inventories (Småros and Holmström, 2000). It is already being used in a variety of settings, including animal tracking, asset management, health care, document tracking and library management, payment processes, tracking baggage and packages (Kampers et al., 1999; Juban and Wyld, 2004; Kern, 2004; Reyes and Frazier, 2007), and mandates by world retail giants like Wal-Mart, Target, and Metro.

RFID is hailed by proponents as an exciting technology application that will transform supply chains into more effective systems, by reducing costs and enhancing supply chain capabilities, creating a significant improvement over the conventional technology, further promising to close the information gaps in supply chain operations. Skeptics characterize RFID as little more than upgraded bar codes that are unreliable and costly, lack common industry standards, and raise serious issues regarding consumer privacy (Reyes et al., 2007). However, compared to the conventional approaches, such as barcode or manual data entry, RFID enables more efficient automatic data acquisition, data identification, and information exchange among supply chain members for tracking

product, sorting, and distribution data collection and analysis (Hou, J-L. and Hung, C-H., 2006; Prater et al., 2005; Smith, 2005).

A variety of benefits are perceived to be associated with the introduction of RFID focuses primarily on improving the efficiency, accuracy, and security of supply chain management for cost savings (Adenso-Diaz and Gascón, 1999; Kärkkäinen, 2003; Kelly and Erickson, 2005; Reyes and Frazier, 2007) that will allow companies to be competitive. Adenso-Diaz and Gascón (1999) further point out that in distribution the quality of customer service is an extremely important factor, such as error-free delivery, reduced lead times, availability of stock, and so on.

In spite of the variety of perceived benefits, it is not reasonable to believe that RFID will totally replace the conventional technology. Yet, its use in supply chain and logistics management is expected to induce another industrial revolution much like the Internet technology explosion (Hou, J-L. and Hung, C-H., 2006).

As industry interest grows and adoption of RFID increases, there is an emerging awareness by academic researchers to engage in scholarly investigation with industry partners to understand RFID integration with SCM practice and performance. This study is motivated by practical importance and the need for better academic research. In general, the adoption of RFID will span many industries; such as retailing, warehousing, distribution, transportation, manufacturing, and third-party logistics (3PLs) and fourth-party logistics (4PLs) providers. Thus the future RFID integrated supply chain studies will not be limited to one particular industry, but will seek to answer "What is the best design for our industry's supply chain?," which still remains an important and challenging question.

2. Literature review

RFID has, for the most part, been flying below the business-innovation and best practice radar. Much hype and press has been given to RFID since the mandates by Wal-Mart and the U.S. Department of Defense (DoD) (Juban and Wyld 2004; Smith 2005; Wicks, Visich, and Li 2006; Hardgrave and Miller 2006; Reyes and Jaska 2006; Wyld 2006; Reyes, Frazier, Prater, and Cannon 2007). Whether RFID represents a new direction in supply chain management theory and practice is a question of no small consequence. Furthermore, it is not reasonable to believe that all firms will adopt RFID (Reyes and Jaska 2006), yet many managers are in a dilemma as to whether RFID is right for their organization or application (Reyes et al., 2007). In some ways RFID is like any other past technological implementation, but in some ways it is not. The actual benefits and risks of RFID coupled with the managers' evolving perceptions about these benefits and risks will determine the speed at which RFID moves from introduction/developmental to maturity stage. Several RFID descriptive papers have been published during the past few years, such as Kärkkäinen and Holmström (2002), Juban and Wyld (2004), Srivastava (2004), Angeles (2005), and Wyld (2006). The purpose of this paper is to aid managers in their quest to determine whether RFID is appropriate for their particular needs and give them some guidelines for implementing an RFID solution.

Although RFID has been around for more than 50 years, recent mandates by Wal-Mart and the DoD have sparked massive interest in it potential for improving supply chain performance (Angeles 2005; Hardgrave and Miller 2006; Reyes and Frazier 2007). Also contributing to this RFID-interest is the rapid acceleration and availability of

computer science and Internet technologies that have been evolving and re-shaping supply chain management processes and practice. As part of the considerations for RFID implementation, managers must filter through the hype and understand what the technology can and cannot do. As with many technologies, the hype and the misunderstanding can be damaging to expectations (Hardgrave and Miller 2006).

One of the barriers to adopting RFID at the forefront of managerial concern is the difficulty in quantifying the cost-benefit ROI (return on investment) in acquiring this technology. Yet there are many factors contributing to RFID adoption, and they are similar to the recent Internet-based e-commerce technology (c.f. Hong and Zhu 2006). These contributing factors are theory-based and are summarized in Table 1 (which is by no means an exhaustive list).

Table 1: Contributing Factors for RFID adoption

Theory	Factors
IT adoption (Beatty, Shim, and Jones 2001)	• Perceived benefits • Complexity • Organizational compatibility • Top management support
Innovation theory (Beatty, Shim, and Jones 2001)	• Entry timing • Organizational readiness • External factors
Technology, organization, environment (TOE) (Zhu, Kraemer, and Xu 2003)	• Technology competence • Firm scope • Size • Consumer readiness • Partner readiness • Competitive pressure
Industrial organizational (Porter 1981)	• Firm performance is enabled or constrained by industry structure
Resource-based view (Barney 1991)	• Presence of resources that meet certain conditions, such as value, rarity, imperfect imitability and lack of substitutability

Other issues that managers should be concerned with include security and privacy (Jones, Clarke-Hill, Hillier, Shears, and Comfort 2004; Boulard 2005; Stuart and Liu

2006). These issues must be at the forefront of any RFID considerations. Organization data security policies must be examined to ensure customer data is not compromised. For the supply chain, security policies are outlined in EPC Network measures (Stuart and Liu 2006) set forth by EPCglobal (an international RFID standards body).

Privacy advocates are concerned about tracking customers (Ferguson 2006; Boulard 2005). Several solutions are available to eliminate tracking of tags after products are sold including "kill tags," password lock, cage approach, active-jamming, and cryptography (Boulard 2005). These techniques need to be explored to determine which is best for an organization's particular application.

3. Methodology

Guided by a review of RFID-specific literature, field studies with firms at different stages of RFID implementation and structured interviews with senior-level supply chain practitioners were used to develop a survey instrument. In order to promote a further understanding of RFID adoption, it was decided to conduct four case studies. The organizations chosen for these cases were companies involved at different stages of RFID implementation. The purpose of the case studies was to identify and compare how these companies had approached the implementation, what benefits had been experienced and future direction.

Semi-structured interviews were conducted with senior-level management in order to gain a broader implementation view. In particular, the issues of interest include:

- Approach adopted for RFID implementation, including techniques used and focus of investment for implementation.

- Internal issues affecting the decision to implement.
- Perceived benefits and limitations of implementation.

All four companies also allowed the researcher to observe their factories and to see their use of RFID in operation. Where appropriate, documentation was also provided as supporting evidence of their RFID use.

When studying these case companies, the extent of RFID implementation was characterized based on the three different forms (reactive, tactical, and strategic) identified by Anon (1997) as referenced in Sohal, Power, and Teriovski (2002). A reactive implementation is simply compliance to a trading partner's request. The tactical approach seeks to extend implementation for improving efficiencies to specific processes within the company. A strategic implementation involves using RFID across the entire supply chain.

4. Case studies

In order to better understanding of RFID adoption, it was decided to conduct four case studies. The organizations chosen for these cases were companies involved at different stages of RFID implementation and are all located in Texas. The purpose of the case studies was to identify and compare how these companies had approached the implementation, what benefits had been experienced and future direction. The organizations are in the health care industry and retail industry; however at the organizations' request their names are withheld. Each case is summarized in table 2 and described next.

Table 2: Case Studies

Case	Industry	Extent of RFID implementation	Benefits
Firm 1:	Health Care	Tactical	• Patient flow management • Improve productivity • Tracking key assets • Reduce human error • Reliable, accurate, and secure measures for tracking, tracing, and authentication of pharmaceuticals
Firm 2:	Health care	Tactical	• Improve utilization of assets • Improve productivity • Improve patient satisfaction
Firm 3:	Retail	Reactive	• Not expecting any benefits
Firm 4:	Manufacture & distributor of perishable consumer goods	Strategic	• Reduce order replenishment cycle time • Improve quality of service • Reduce labor costs

4.1. Case study 1

The organization is in the health care industry and is in phase two (of four) RFID implementation project. Their extent of RFID implementation would be classified as tactical. Their primary interest is to track patient flow and improve the cycle time to turn the beds. In order to improve this productivity, patients are provided RFID-wristbands at check-in and their movement during the patient-care delivery system is monitored. At check-out, housekeeping is automatically notified allowing them to reduce the "waiting-to-be-notified" cycle. By reducing this time, the patient room can be cleaned and prepared for the next patient—thus improving the bed-turnover rate.

Secondary uses of RFID include tracking key assets and reducing human error. About 10,000 pieces of movable equipment were identified as "key" assets and tagged with active tags. The problem is that staff members were spending 20-30% of their time searching for equipment. Moreover, they were loosing about 10-15% of their inventory annually. The use of RFID tags have saved the nurses' time in locating the equipment.

By improving the productivity allows the nurses to spend more time on patient care and it is perceived that human errors have been reduced – including more accurate billings.

A desired benefit of RFID is to have a reliable, accurate, and secure measure for tracking, tracing, and authentication of pharmaceuticals. However this has not been addressed and is ear-marked for the final phase of the implementation project.

4.2. Case study 2

The organization is also in the health care industry and is in the preliminary stages of planning their RFID implementation project. Their extent of RFID implementation would be classified as tactical. Their primary interest is to improve their equipment utilization. Currently, the organization does not do a satisfactory job of tracking their equipment usage. If they cannot locate the needed equipment, then just procure more. Hence, by using active tags the under and over utilization of assets can be identified automatically, and they can gauge what is needed.

The plan is to identify the "top 5,000" critical equipment. The perceived benefit of improved equipment utilization can lead to time saved by staff employees, thus leading to improved productivity, with the time transferred to "patient satisfaction."

4.3. Case study 3

The organization is in the retail of consumer package goods industry and has completed their RFID implementation project. Their extent of RFID implementation would be classified as reactive. Their primary interest is to "slap-and-ship" cartons and palletized goods as compliance to their customer's request.

This firm has realized increase in labor costs due to their perceived 'non-value added' process of applying active tags to cartons and palletized goods prior to shipment. At this point, they are not utilizing the use of the RFID tags and thus not realizing any benefits.

4.4. Case study 4

The organization is in the manufacturer (and distributor) of consumer perishable consumer goods and has completed their RFID implementation project. Their system was launched during the spring of 2006 and extent of their RFID implementation would be classified as strategic. Their primary interest is to use the POS-information available from their customer to speed-up their order-replenishment cycle time to the retail stores. Their interest in RFID was motivated by the Wal-Mart mandate (but not part of the mandate). It was stated that if a "100-ton gorilla says this is a good technology, then it must have some merit." Moreover, adoption of the technology was also aligned with their strategic supply chain goals with their key trading partners.

The realized benefits include an average of forty-minute reduction per truck in loading their out-bound delivery trucks. In addition to the reduction in order-replenishment cycle time, the use of RFID tags have alerted the users when items are being loaded into the wrong truck – which improves the quality of service to customers and savings in additional transportation of delivering the "right product" by "special hot-shot delivery."

5. Survey

We engaged in multiple-phase survey research to investigate the current state of RFID diffusion and to identify implementation drivers and barriers. First, guided by our literature review and interviews with senior-level supply-chain practitioners, we developed a survey instrument for use in our study. After incorporating feedback from a number of academic researchers, we administered our instrument to approximately 5,000 members of the Institute of Supply Management (ISM), a society of supply chain management professionals. The survey recipients, all but 200 of whom practice in the United States, were in targeted SIC codes (Table 3; those industries most likely to benefit from RFID). Upon receipt of all completed surveys, we used exploratory data analysis methods to gain insights into the motivations for RFID adoption, to better understand the barriers to adoption of this technology, and to identify opportunities for using this technology to improve supply chain performance.

Table 3: Targeted SIC codes

Division	Code	Description	Number of Recipients
D: Manufacturing	20	Food and kindred products	366
	23	Apparel and other finished products made from fabrics and similar material	48
	25	Furniture and fixtures	51
	30	Rubber and miscellaneous plastics products	171
	34	Fabricated metal products, except machinery and transportation equipment	458
	35	Industrial and commercial machinery and computer equipment	370
	36	Electronic and other electrical equipment and components, except computer equipment	933
	37	Transportation equipment	293
	39	Miscellaneous manufacturing industries	1,695
E: Transportation, communication, electric, gas, and sanitary services	40	Railroad transportation	36
	42	Motor freight transportation and warehousing	22
	44	Water transportation	25

	45	Transportation by air	87
	47	Transportation services	81
F: Wholesale trade	50	Wholesale trade-durable goods	188
	51	Wholesale trade-non-durable goods	77
G: Retail trade	53	General merchandise stores	23
	54	Food stores	29
	55	Automotive dealers and gasoline service stations	19
	56	Apparel and accessory stores	18
	57	Home furniture, furnishings, and equipment stores	10

Our survey instrument was designed to reflect these research goals, with primary questions focused on factors that make RFID attractive (or unattractive) to firms, and secondary questions focused on assessing the nature and extent of any RFID-related improvements that have been realized. From those firms whose RFID implementation was complete or well underway, our instrument solicited any "lessons learned" that would be of value to the broader RFID market. The logical flow of the instrument is presented in Figure 1.

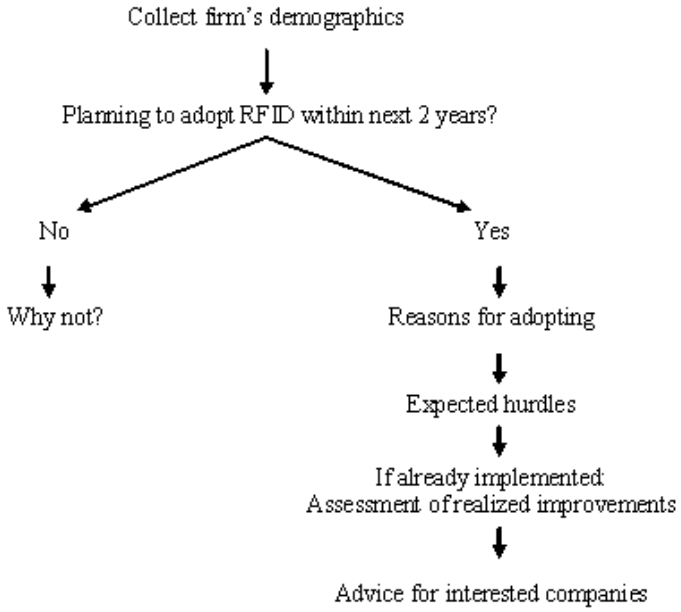

Figure 1: Survey Instrument Logic

The finalized survey instrument was administered in mid-spring of 2005. (The relevant parts of the instrument are included in the appendix.) All 5,000 recipients received a letter of support for the research from ISM, which was used as the primary cover letter introducing this research. A second cover letter was included in the mailing to explain the purpose of the research and give contact information. A follow-up postcard was sent within three weeks of the initial mailing. Two additional follow-up e-mails were also sent over the next few weeks. Data collection was closed in early summer 2005. A total of 98 letters or postcards were returned as undeliverable, so our initial target sample was reduced accordingly.

In all, we received useable responses from 663 targeted individuals – a response rate of approximately 13% – as well as more than 200 e-mail replies: 1) stating that their company is not considering RFID; 2) stating that company policy forbids participation in such surveys; or 3) requesting to be removed from the e-mail list. Preliminary evaluations of our final sample raised no serious concerns with respect to its composition. We performed a Mann-Whitney nonparametric test for differences in responses rates across industry code. No difference at the 0.10 significance level was observed. To evaluate the potential of non-responses bias, we compared the responses of early and late respondents (Armstrong & Overton, 1977; Lambert & Harrington, 1990), the last 10 responses being considered representative of non-respondents. T-tests on 10 randomly selected survey items were insignificant, suggesting no serious concerns with respect to non-response bias.

6. Findings

Out of the 663 respondents, 67 (10%) indicated either current use of RFID technology or RFID implementation that was well under way. Another 86 respondents (13%) reported that their firms are seriously considering RFID implementation in the coming two years. All in all, results of this portion of the questionnaire, summarized in Table 4, indicate that RFID technology is moving beyond the narrow domains of "innovators" and "early adopters" and is increasingly a choice of the important "early majority" (Rogers, 1995).

Table 4: The Current Status of Companies' Adoption Plans for RFID Tags

We do not plan to implement RFID tags in the next two years	510	76.9%
We are seriously considering implementation of RFID tags in the next 1-2 years	86	13.0%
We are in the process of implementing RFID tags	46	6.9%
We have completed implementation of RFID tags	21	3.2%
Total:	663	

Regarding the items on which RFID technology is being (or will be) used, responses to our survey (Table 5) indicate that almost half of early adopters use or intend to use RFID at the individual product level. The cost of RFID tags had many proponents asserting that widespread, product-level use of this technology wouldn't occur until it crossed a "nickel-a-tag" barrier. Our results indicated that even with RFID tag cost at approximately $0.20-$0.25 each, some firms are already in position to exploit this technology at its "ideal" level.

Table 5: Initial Use of RFID Tags

Individual product	61	48.4%
Case	27	21.4%
Pallet	25	19.8%
Container	9	7.1%
Other	4	3.2%
Total:	126	

Table 6 presents results of a finer-grained analysis of the target of RFID implementations. In this case, respondents were simply asked how their firm used or planned to use RFID technology, and they were free to check any number of the options provided. Percentages in Table 4 are based on the number of respondents who answered this question. Not surprisingly, current or planned use of RFID technology to track parts at the individual part level (51.5%) or case/pallet/container level (65.3%) was reported by a majority of respondents. A large number of our respondents also indicated use, current or planned, of RFID technology to automate processes such as part/item location (42.6%), inventory counting (47.5%) and control (49.5%), inventory replenishment (52.5%), and the tracking of materials handling equipment (23.8%).

Table 6: How do you plan to use RFID Tags?

Track parts at case/pallet/container level	66	65.3%
Help automate inventory replenishment	53	52.5%
Track parts at individual part unit level	52	51.5%
Help monitor inventory usage	50	49.5%
Conduct inventory counts of items in storage	48	47.5%
Locate parts or equipment within facility	43	42.6%
Track equipment (pallets, carts, trailers, etc.)	24	23.8%
Other	13	12.9%

Note: The second column is the number of responses. Respondents were allowed to respond to multiple items. The percentage in the last column is based on the number of respondents who answered this question (n=101).

When asked at what per-tag cost RFID technology would make economic sense for their companies, our respondents diverged dramatically. Some reported a threshold per-tag cost of $0.001, while others saw sufficient economic benefits possible with a per-tag cost of $10.00. The average threshold cost reported by our respondents was $0.374, with a median of $ 0.10 and a mode of $0.05. When asked the average dollar-value of the

units that would be tagged first, our respondents reported values that ranged from $0.32 to up to $300,000 – with a majority indicating an average dollar value in excess of $100.

Ample anecdotal evidence suggests that RFID adoption is being driven by large organizations such as Wal-Mart and the U.S. Department of Defense. Given the channel power held by such organizations, we explored the likelihood of their exploiting that power in capturing the bulk of RFID-related benefits by asking respondents to rank who they thought would benefit more from RFID: their firm, their firm's customers, or their firm's suppliers. Table 7 summarizes these results. From the respondents' perspectives, powerful customers are not mandating a new technology from which only the customers will benefit. In fact, as many respondents listed their own firms as the biggest RFID beneficiary as did those listing their firm's customers as the primary beneficiaries.

Table 7: Perceived Rankings of Channel Members Benefiting from RFID Tags

	Most	Middle	Least
Customer	44	28	50
Company	44	55	22
Supplier	38	36	46

For those respondents who already had implemented RFID technology, we asked them to report on realized improvements in eight areas (Table 8). A 7-point scale was used with 1=worse, 4=no change, and 7=better. The bars on the right side represent the results of the Duncan multiple comparison test for differences in means (each bar represents groupings within which the differences in means are not statistically significant). Although respondents reported RFID-driven improvements in all areas we targeted, not surprisingly the accuracy and availability of information experienced the greatest perceived improvement. RFID also was perceived to have facilitated increased process automation and improved customer service. Interestingly, our respondents

reported only moderate improvement in one highly touted RFID-related benefit – more efficient allocation of supply-chain related personnel; respondents' ranked labor-cost improvements last among those areas in which RFID's benefits had been realized.

Table 8: Realized Improvements

Variables	Mean			
Accuracy and availability of information	5.23	|		
Level of process automation	4.96	|		
Level of customer service	4.80	|	|	
Operations capabilities	4.76	|	|	
Inventory levels	4.69	|	|	|
Lead time	4.65	|	|	|
Overall operating costs	4.46		|	|
Labor cost	4.26			|

Note: Values greater than 4.00 indicate improved performance.

In our survey we also tried to elicit perceived barriers to RFID implementation. Those respondents not considering implementation in the next two years were given a list of possible reasons against RFID adoption and asked to check all that applied. Their responses are summarized in Table 9. Interestingly, while the cost of the technology itself was seen as a major reason against adoption, many respondents questioned either RFID's applicability to their particular line of business or the technology's ability to deliver sufficient benefits.

Table 9: Reasons for Not Planning to Implement RFID Tags

Not applicable in our business	187
Initial costs are too high	140
Expected benefits are not enough	138
Our system works fine	97
Technology too new or standards not set	79
Too busy to consider it	64
Security or reliability issues	20
Other	62

7. Discussion and managerial implications

Our survey results show that most firms are not rushing to embrace RFID. In fact, many firms see little reason to be early adopters, or question the extent of proclaimed benefits. Further, additional comments from respondents highlighted some general RFID-related fallacies.

7.1. The Fallacy of First-Mover Advantage

Although a variety of technological diffusion models assert that early adopters reap the majority of the benefits from new technology (e.g., Rogers, 1995), competing frameworks caution against treating such benefits as guaranteed (Barney, 1991). Many of our respondents would seem to conform to this latter school of thought, in essence arguing that while RFID technology might one day be essential for survival, its very nature – an open-architecture technology that can be adopted at relatively low cost – makes it unlikely to support true competitive advantage at the firm level. One respondent's comments are particularly compelling in this regard: "We are typically at the trailing edge of technology and buy into it [only] when costs come down." That is, this respondent's firm will ultimately use RFID technology, but only when early adopters have forced the emergence of a "dominant design" – in essence an industry standard – easily imitated and exploited by competing firms (Anderson & Tushman, 1990).

As RFID technology improves and prices decrease, adopting it will become easier and cheaper. Consulting and technology firms are already advertising their RFID compatible products (Boyle, 2003) and solutions, and consulting firms with reliable solutions will quickly offer these to entire industries (Schwartz, 2005). Thus, while an industry as a whole might benefit through such evolution, it is unlikely that any one firm

will, simply because it adopted RFID early, continue to outperform its competitors solely on the basis of this technology (Barney, 1991).

To illustrate, Wal-Mart is expecting many of its suppliers to equip cases and pallets with RFID tags. In the short term, Wal-Mart might enjoy some competitive advantage through such use. However, unless Wal-Mart can prevent its suppliers from shipping similarly tagged pallets to Wal-Mart's competitors, as time goes by Wal-Mart will find itself back in a position of competitive parity with respect to RFID-enabled processes. Indeed, it is entirely possible that, by investing early in the technology, Wal-Mart will have partially funded the RFID implementation efforts of its competitors.

We do not argue that Wal-Mart will not benefit from RFID technology. Indeed, many devotees of the Resource Based View (RBV) of the firm (Barney, 1991) would argue that Wal-Mart's use of modern logistics technology is at the heart of its success. RBV proponents would rest such assertions not on the technology Wal-Mart employs, however, but on the socially complex (and therefore imperfectly imitable) ways in which Wal-Mart has woven logistics technology into its competitive strategy. Others might imitate Wal-Mart's technology, the argument would go, but it is exceedingly unlikely that they could imitate the myriad ways in which Wal-Mart has used the technology to its advantage.

7.2. The Fallacy of In-store inventory uses

RFID futurists visualize the day when every item will have an RFID tag, and provide these advantages for the retailer: instantaneous counts of inventory; faster, automated communication about inventory orders to distribution centers; and control of theft because no product will be able to leave the store without being scanned. While these

advantages do sound interesting, many doubt whether they will come to be. Bar-code technology was supposed to simplify inventory-related tasks, but a number of organizational realities have led to reduced managerial confidence in bar-code inventory counts. Poor management practices can derail the potential benefits of promising technologies. For example, one common practice of retail management is to reduce employee headcount as much as possible, which may result in poor training, lack of monitoring, and little managerial follow-up; as they pile-up, the new technology's potential is reduced further and further. Some comments to our survey bear this out. One respondent saw RFID as a technology that will be valuable only "after a facility is lean and advanced in material movement." That is, RFID's promise will only be realized when it is coupled to effective business processes; it cannot correct poor practices on its own.

8. Conclusions

RFID technology is being pushed by retail giants (like Wal-Mart) as having great potential for reducing costs and improving customer service. Others are responding with skepticism and, at times, rejection of this new technology. RFID's critics point out that:

- The expense of creating supply chain solutions while waiting on emerging standards will create long delays and expense overruns (Lundquist, 2003).
- Tracking of so many items can create a huge data deluge (Fonseca, 2004).
- Tagging every item will be too expensive (Murray, 2003).

Nevertheless, many early adopters of RFID tags are applying a "slap and ship" strategy to comply with mandates and are, not surprisingly, experiencing more costs than benefits. Concerns about cost and return on investment are well known barriers to

adoption in supply chain operations. But as this study revealed, RFID technology likely isn't applicable to all industries, and the current systems being used for supply chain management decisions may be working fine.

Survey respondents who had already implemented RFID were asked to provide advice to others considering this technology. They cautioned against too-rapid adoption – "Don't; RFID isn't going anywhere; you have time" and "Wait for [the next generation] and combine technologies" – and adoption without a clear understanding of what is expected from the technology – "Define your goals and requirements first." Those contemplating adoption were also warned that RFID won't fix processes that aren't working properly, and that RFID implementation without senior management support is a risky proposition.

In that light, Kim and Mauborgne (1999) argue that a cross-company perspective is essential when using wireless product identification as the basis for value innovations. However, whenever solutions cross firm boundaries, proprietary gains evaporate. This "balancing" of issues in the supply chain is a classic supply chain management problem. In the context of RFID early adopters it is exaggerated. As can be seen from the comments, RFID implementation is not a "no-brainer"; rather it must be approached with a serious regard to a firm's competitive position and the fundamental way it goes about competing. As with any technology, RFID opens firms up to problems that must be dealt with and issues that should be avoided. We trust that our survey can serve to direct firms in assessing their own abilities and competitive position as they determine whether RFID is for them.

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