Looking Backwards to Look Ahead: Lessons from Barcode Adoption for RFID Adoption and Implementation

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Abstract

This paper compares the adoption patterns of two automatic identification technologies i.e. Bar codes and RFID (Radio Frequency Identification). The paper juxtaposes the historical events that were significant in the adoption of Bar codes with the contemporary events that are taking place in the RFID space. Based upon the review of bar coding literature and data collected from semi-structured interviews, the paper identifies critical themes and eight key enablers underlying the adoption of bar codes and suggests how understanding of those themes and enablers can inform the adoption and implementation of RFID and similar emerging technologies.

Keywords: Adoption, Automatic Id, RFID, Barcodes, Platform Innovation, Emerging Technology

1. INTRODUCTION

Automatic Identification is the process of identifying and tracking objects through the use of technology devices such as magnetic readers, bar codes and radio frequency. While keyless data entry devices have existed since 1800's when they were used as reading aids for the blind, the invention of electronic digital computers led to the search for better methods of data entry (LaMoreaux, 1998).

With increase in the logistics and inventory costs for supermarkets in the mid-1900's there was a growing need to find an efficient means for automatic identification of products without manual inspection. Two graduate students at Drexel institute solved the problem by relating it to Morse code in which messages sent as dots and dashes were read automatically leading to the birth of the Bar code.

RFID (Radio Frequency Identification) is a means of automatic identification of objects using radio signals. While it has been around since the 1940's its commercial application is relatively recent.

In this paper we juxtapose the historical events in the adoption of bar codes and compare them with RFID adoption patterns. We suggest eight key enablers that were critical in Bar Code adoption and that also inform on the adoption and implementation of RFID technologies.

Bar code

Bar codes were invented in 1949 and by 1952 Norman Joseph Woodland and Bernard Silver were issued the first patent for a bar code type product. The first commercial use of the Bar code was in 1967 when RCA installed them on the first scanning systems at a Kroger Store in Cincinnati. It soon became apparent that an industry standard was needed so that different equipment manufacturers, food producers and dealers could readily adopt it. In 1969 a consortium of food distribution trade associations called the Uniform Code Council (UCC) began to develop a standardized barcode for consumer items called the Universal Product Code or the UPC. In 1973, an Ad Hoc committee composed of grocery industry executives chose the 11-digit, linear bar code that is now commonly referred to as UPC. The initial UPC was a linear one-dimensional bar code, which contained manufacturer and brand information but no uniquely identifying data. In 1974, there was agreement in the UCC on adopting a common standard for the UPC. Thus began the new era of automatic identification of consumer products. While most barcodes are still one-dimensional like the original ones, two-dimensional bar codes, which can carry more data in a smaller area, are commonly used in shipping markets and transit companies such as UPS and FedEx [10].

Bar codes suffer from several limitations. Objects must be physically manipulated to align with scanners to get a line of sight. Barcodes are exposed to vagaries of the environment and with natural wear and tear become inefficient. This is quite evident when many times checkers face difficulties in scanning an item. Bar codes require sequential processing of data and need to be brought in line of sight of the scanner, one item at a time. Also bar codes carry limited data, which is static in nature; hence the identification is usually at the product level unless special efforts are made to identify the item. Radio Frequency Identification or RFID has the potential to alleviate the problems presented by barcodes.

RFID Technology

The United States Air Force developed RFID technology in the 1940s to differentiate between friendly and enemy aircraft in World War II. Though patented in 1973, it has only become commercially and technologically viable for commercial applications in recent years. As compared to barcodes RFID has the potential to provide improved data collection and handling through more granular data, geospatial/physical alignment independence, parallel processing of multiple scans simultaneously, and internal placement in objects.

Basic identification data is carried in transponders known as tags, read by transceivers that decode and transmit data to attached computers for processing. There it can be associated with database information such as product, business processes and organization data. The data in a tag (also referred to as tag id) can identify the object associated with it in terms of its manufacturer, brand, model and unique serial number for the object. Thus data are granular to the specific product level. The tag consists of a small microchip attached to an antenna and communicates via radio frequency with a transceiver or tag reader. A tag has geospatial/physical alignment independence in that it may be read without any line of sight. Tags can be read at a rate of several hundred reads per second (essentially simultaneous) and from a distance of several meters. The tag can be attached to the outside or the inside of a product that is made of non-conducting material, without read problems or wear and tear. RFID tags have a unique ability to be active (battery power source) and can be combined with other technologies to capture contextual information such as temperature variations to create a history of the object through its life cycle.

Up until now, RFID has been too expensive and too limited in adoption levels to be practical for many commercial applications. With recent reduction in tag and RFID systems costs, RFID can solve many of the problems associated with barcodes. Unlike barcodes RFID does not require a "line of sight" to track products and no manual intervention is needed. Radio waves travel through most non-metallic materials except liquids, so they can be embedded in packaging or encased in protective plastic for weatherproofing and greater durability. Additionally, tags have microchips that can store a unique serial number for every product manufactured around the world and can also be updated.

Business Impacts and Benefits from RFID

The power of RFID lies in its ability to capture or acquire more data, automatically without manual intervention, in almost real time. The data can be the unique identity of each item in its location and could potentially help in tracking the item in real time and creating rich profiles, which could be the history of the object from its time of creation to its eventual destruction. The

physical object is no longer an abstraction of reality but tied to reality itself. The data is available at the item-level and multiple items can be scanned simultaneously using radio waves. This empowers businesses by allowing them to create automated inventory control systems, enabling real time inventory management, and therefore making their supply chains more efficient. Database updates could occur in real time, resulting in more dynamic systems. This is analogous to having a live video versus a snapshot of the process in time.

The potential benefits from RFID for consumer product applications relate to ease of use. Manufacturers, transporters and retailers scan millions of bar codes every day; however each may use their own formats, and usually the bar codes are scanned only at a single point, such as checkout, due to the processing burden of arranging manual orientation and line of sight. By integrating RFID at each level in a supply chain, every party involved in the lifespan of a product can potentially scan every product within a scanner-enabled supply chain location at any time. This includes not only manufacturers or retailers but also regulatory bodies such as the FDA, end consumers and even waste disposal and recycling organizations. RFID has the potential to lower costs of inventory management, supply chain management and retail checkouts as no individual worker need be present during a scanning.

If used in this manner, RFID technology will provide "real time" information in tracking products and opportunities for creating rich product life-cycle profiles. These could be used to increase theft prevention, inventory management accuracy and quality control. Besides these three apparent direct benefits, RFID deployment can result in many indirect benefits such as better business customer management, enhanced partner collaboration, and more efficient business processes resulting from process mapping and through gaining strategic insight into product-level life-cycles.

Over the last decade, RFID has been implemented to improve goods tracking throughout supply chains (SC), access control for security, livestock management, waste management tracking, inventory control, and transportation fleet management. As RFID use grows in its trajectory of becoming a commonly adopted technology, firms have begun thinking up new ways of leveraging RFID's technological capabilities. One forefront in these innovations will be making active RFID tags, which can store and provide rich status information from sensors on tagged items.

Leading retailers such as Wal-Mart and Target and manufacturers such as Proctor and Gamble and Gillette have endorsed the technology and are pilot-testing its use for full-scale retail implementation.

2. BAR CODE AND RFID ADOPTION TIMELINES

While the commercial use of bar codes began in 1974, the adoption of bar codes did not pick up until the early 1980's when mass retailers K-Mart pushed for its adoption. It took nearly 20 years for full-scale adoption of bar codes. Adoption of RFID is likely to follow a similar pattern but with a shorter time cycle. This reduction in time is likely due to advances in information technology and quicker responses to environmental forces. Even though RFID has been around for many years, its commercial application has been relatively recent and has picked up only in the later part of 1990's and early 2000's. Table 1 and Table 2 in the Appendix present the timeline of critical events for Bar Code and RFID adoption.

3. DATA COLLECTION & ANALYSIS

We wished to explore the key enablers in the adoption of RFID by organizations and understand what factors were contributors or deterrents and may impact their decision to adopt and integrate RFID internally. We were curious not only about the decision to adopt but also whether the organizations intended to integrate data generated by RFID with internal systems and processes. In such a case, interpretive research focusing on exploring the unknown phenomenon best serves to initiate a valid and accurate line of inquiry (Krippendorff, 1980) precisely our underlying research goal. To accomplish the above-mentioned goals and to develop a better understanding of the adoption process, we conducted in-depth, semi-structured interviews using a convenience sample.

The interviewees were executives and RFID program managers and supply chain managers across 10 organizations (12 interviews) involved in RFID initiatives at some level. We sampled from three perspectives in order to triangulate and, thereby, strengthen our understanding of RFID adoptions. These perspectives were the adopter perspective (7 firms and 8 interviews in

three industries: manufacturing, retailing, and logistics), the implementer perspective (1 top IT consulting firms and 2 interviews), and the vendor perspective (2 firms and 2 interviews). Table 3 in the Appendix describes the profiles of organizations interviewed and their decision status on RFID Adoption and Integration.

The interviews were conducted over a period of three months (May-July, 2005) and were either face to face or over the phone, lasting between one and two hours. The questions for the interviews were a mix of open-ended questions and closed questions to allow both the flexibility of exploring new contexts but also to help maintain focus on some of the previously identified relevant themes from bar code adoption and prior literature. These themes emerged from the data and were later developed conceptually, because of what we found from practice.

The interviews were recorded and later transcribed. The author coded the interview data in an effort to extract key ideas underlying the decision to adopt RFID for managers evaluating emerging technologies such as RFID. This coding process involved the first author identifying patterns and underlying themes that emerged from quotations in the raw text, excerpting them and bringing them to the other author for joint discussion and refinement over a period of 7 months and more than 20 hours of discussion.

4. EIGHT KEY ADOPTION ENABLERS FOR RFID

In executing this study comparing the adoption vector of barcodes 30 years ago with RFID today in the commercial arena we have been able to extrapolate eight key enablers and evaluate their current status in RFID settings. In addition to the literature review to collect information for comparison, we conducted interviews with managers in charge of RFID research and implementation efforts at 10 firms in industries ranging from logistics and manufacturing to marketing and retail to find out their current outlook on each of the eight enablers. We present these findings in the following sub-sections as a guide for those involved in RFID projects or otherwise interested in successful RFID implementation and adoption in commercial applications. Table 4 in the Appendix summarizes these findings.

1. Establishing the Standards

Development of standards is critical in the adoption of any new emerging technology. Prior research on standardization has suggested that standardization emerges as a result of an inter-firm cooperation strategy. This theme of literature has examined the incentives to technological compatibility (Besen & Farrell, 1994); collective nature of organizational action in the emergence of standards (Vab De Ven & Garud, 1989) and the governance of collaborative standardization (Antonelli, 1994). In the case of bar codes for an automated checkout system to work, supermarkets and packaged goods companies had to agree on one standard to translate lines into numbers representing the same product-model consistently to avoid confusion. The grocery industry realized this challenge early on and created an Ad Hoc committee with representatives from different groups (i.e. manufacturers, distributors and retailers) in 1970. The Ad Hoc committee worked towards accomplishing the goal of a common standard. Finally, in 1973 through the efforts of the Ad Hoc committee representatives of supermarkets and their counterparts from consumer-goods companies agreed upon the Universal Product Code (UPC) to handle the issue of data compatibility.

In the case of RFID standards or rather the lack thereof, companies appear to be adopting a wait and watch approach thus further delaying adoption. As interviewee from organization A which is a Home construction retailer stated, *"We find benefits but RFID is not on our priority list and we don't think we are ready as we don't have the infrastructure and expertise to process huge amount of data that would be generated by it and make sense out of it. Lack of standards and cost of tags and readers is prohibitive."* Besides hardware, software, and middleware standards, another important issue that needs to be dealt with is the adoption of legal standards and intellectual property rights incorporating potential points of contention such as who owns the tags, can they be deactivated, and the management of information on the tags. All these legal-property rights aspects may delay adoption further. Many business and technology experts expect that resolving these standards and legal-property rights issues may help in accelerating RFID adoption. The proactive role of standard making body EPC global and the movement towards the GEN2 standard is likely to promote more widespread adoption of RFID.

2. Solving the Chicken & Egg Dilemma: Network Effects, Critical Mass and Economies of Scale

The adoption of bar codes posed the classic chicken and the egg problem. Why would manufacturers put bar code on their product if there were no retailers to scan it? And why would retailers invest in scanning equipment unless a significant amount of their product was coded (Brown, 1997). This scenario is similar to the adoption of any technology that exhibits network effects i.e. the greater the number of adopters of the technology, the more beneficial it becomes for its users. Prior research has indicated that in technologies exhibiting network externalities adoption may be driven through sponsorship and support (Katz & Shapiro, 1986; Riggins, Kriebel & Mukhopadhyay, 1994)]. Adoption of an emerging technology needs to attain a critical mass before the technology can really take off (Markus, 1987). The Ad Hoc committee recognized the effect of network externalities and the need to attain critical mass. It was their leadership efforts in convincing the groups involved that led to the diffusion of barcodes. The adoption of barcodes by 1350 manufacturers led to almost a ten-fold increase in the probability of adoption of scanners by retailers. Similarly the adoption of scanning by 360 retailers led to a significant increase in the probability of adoption by manufacturers (Haberman, 2001). This scenario is likely to play out also in the case of RFID adoption with similar network effects and with benefits to gain for all from full-scale supply chain integration. As interviewee from consulting firm B mentioned, *"My definition of adoption is a continuum. The continuum has to do with the amount of integration you are putting into your business product. So slap and ship with absolutely no integration what so ever, they are either return lifted or on your return data all the way to a fully integrated solution where you are tracking tags through your supply chain individually."* Also, greater demands for the tags would result in economies of scale in its production and further reduction in tag costs. This is likely to have a cascading effect as reduced tag costs are likely to further drive adoption. The standard making body EPC global (enabler 1) may need to take lead to help cross the critical mass barrier. Another component of affecting this enabler is drive from dominant market players (enabler 3).

3. Dominant Market Players Driving (Mandates)

Initial bar-code adoption was very limited. In March 1976, Business Week published an article titled 'The Supermarket Scanner That Failed' . (Haberman, 2001). It was widely believed even though incorrectly that the experts had predicted 5,000 stores with scanners by 1975 instead of the 100 that were actually there. This misperception was caused because the experts had estimated that the savings from scanning would justify the investments if there were 5000 stores by 1975. It was only in the early-mid 1980's that bar codes really took off. According to Stephen Brown (1997), "What really turned the corner was not the grocery industry, but the mass merchandisers. When the mass merchandisers, most notably Kmart, decided to adopt the system, that built a momentum that never stopped."

The prophecies of doom and gloom are not new to RFID. Many consider the technology over-hyped. This was no different at the time of the bar code. Wal-Mart provided market leadership in the adoption of UPC, or universal product codes, and is exhibiting the same leadership in the adoption of RFID technology by mandating its adoption among its top suppliers. *"What I see happening now is that Wal-Mart is clearly the biggest driver in RFID technology in the business area. There are a couple other drivers in let's say Pharma. There is chain of custody and issues around counterfeiting and safety for consumers that are some very important issues for the pharmaceutical groups. From a general retail and consumer package goods manufactured perspective, Wal-Mart is the 800-pound gorilla and Wal-Mart is driving"* according to the consulting manager from organization I. Partner mandates are an important driving force for adoption, but mandates alone were not enough to drive barcode adoption and may not be enough to drive suppliers towards full scale integration of RFID without a clear innovation focus (enabler 4).

4. Focusing on the Innovation Opportunity: Business Case & ROI

It has been mentioned in many current business reports that while the retailers might benefit from the adoption of RFID the suppliers do not find a compelling business case to adopt. A similar scenario played out 35 years ago in the case of bar codes. The Ad Hoc committee provided leadership to identify direct and indirect short-term and long-term benefits for manufacturers, retailers and distributors.

Economic benefits and ROI were not realized in the first few years until wide acceptance and adoption of the UPC code (Haberman, 2001). Also, while the barcodes were initially intended to automate checkouts and be beneficial for the retailers some of the major benefits such as operational efficiencies and information management along the supply chain became apparent later.

At present some suppliers view RFID as an opportunity and integrate the technology with their internal processes in order to re-engineer them and make them more efficient. According to the manager of end-user organization G, *"we recently created as a company, which is called the Innovation Experience. It is like if you go to trade shows, they always have a lot of booths and different things, different technology. As a company, we recognize how important it is to show and also allow different businesses to recognize the new technology. We then invite our business to see how they can relate it to their existing processes"*. Some other suppliers are using RFID to be more attractive and appealing to their customers. However many suppliers, those that are only tagging and shipping to meet the mandates are viewing RFID as the cost of doing business rather than a strategic resource. These suppliers are unlikely to see any immediate benefits until widespread adoption takes place. At this intermediate level for enabler three, we believe the persuasive role of standard making bodies (enabler 1) and partnership collaboration (enabler 5) are critical to move to the next level of maturation.

5. Collaborating among Partners

Barcode adoption required leadership and direction from the Ad Hoc committee which was an inter-industry committee representing the grocery industry. The committee was formed of chief executives with five representatives from grocery manufacturers and five from distributor associations, which included two chains and a wholesaler (Brown, 1997). This grouping enabled a collaborative approach towards solving the problems faced in the adoption of the technology. The interests of manufacturers, retailers and distributors were all given due importance. Also the people representing the committees had decision making power.

When RFID information is used across supply chains with inventory management systems it becomes an interorganizational tool with greater potential benefits derived from increased partner participation and commitment and subsequent refinements of organizational processes. The ability to acquire and communicate unique and relevant information about tagged items/entities at any given place and time almost instantaneously, gives RFID technology the potential to reduce costs, increase operational efficiency and improve performance. Interview data from organizations indicates that partner collaboration is already happening. The consulting manager from organization I, talking about a dominant retail partner and its suppliers said, *"What they are trying to do is to take all of this data and provide it back to their suppliers and say, "You manage your product better within our stores and supply chain for us. You need to tell us when more efficient ways are to be ordered. You need to manage your promotion more effectively.""* Associated information could be used in many different ways to understand and improve processes and significantly enhance competitiveness. Hence it is very likely that due to RFID's trans-supply-chain benefits, adoption will be more effective when done jointly through collaborative arrangements (Yang & Jarvenpaa, 2005) rather than individually by isolated partners. Partner relationships in a dyad or their memberships to professional and standard making bodies may play an important part in driving adoption. At this point these relationships appear to be nascent for RFID. Wal-Mart and other leading proponents of the technology should work closely and collaboratively with their partners and also use standard making organizations such as EPC global (enabler 1) as a platform to address the concerns of their suppliers.

6. Developing Supporting Technologies

In the case of bar codes, despite being invented in 1949, barcode technology did not take off for over two decades because lasers and computers were very expensive and were required to effectively derive significant benefits from bar code adoption. This exemplifies the need for supporting technologies to co-evolve in order to support infrastructure type technologies such as bar codes and RFID. Large benefits are expected from the integration of RFID with other applications and systems. Thus, RFID will require the development of new hardware, software and middleware for full-scale integration of the technology with existing systems. As mentioned by manager from organization G which is in the paper industry, *"Ideally, you want to have more re-points in between and have the third party (3pl) the logistics company. The D.C. also has a responsibility on it. So, you can see points and*

that is how the tracking is supposed to work but until the whole infrastructure is ready and until the EPC-Network is ready; it is very spotty."
At present it is unclear what all of these additional technologies will be, but some of them may be better batteries at lower cost and sensors and memory for active tags. In the long run, once RFID matures, supporting technologies will flourish as adoption will accelerate (enabler 2). At present this is an enabler that can be refined by building the business cases (enabler 4) among collaborating partners (enabler 5) and with standards bodies (enabler 1).

7. Addressing Consumer Concerns
During early bar code adoption, consumers were not ready to accept products without price stickers, as they did not trust that retailers would not change prices behind their backs. Issues of trust forced several state legislatures to pass laws mandating price labels thus forcing retailers to continue putting price stickers on products. Similarly in RFID adoption, concerns about consumer privacy issues are rampant. Some consumers fear that all of what they purchase can be scanned easily by someone outside their house. Thus, it is important to provide information and educate consumers on what RFID technology can or cannot do and demonstrate that some of their concerns are unfounded. The interview data suggests that these concerns are more perception than reality but still need to be addressed. According to RFID program manager from Antenna and Label maker organization D, *"There are always folks who have those concerns. And some are legitimate to what I would call infrequent examples of filtering personal data. But really nothing to date that has been significant with RFID. Frankly in terms of personal security you take more risk in handing clerk your credit card than putting an RFID tag around it. Now it's because of the press around those issues a lot of the venders, technology providers, and standards organizations are heavily investing time in security systems."* As the tags become more pervasive, due to the network effect RFID consumer concerns should mimic the pattern experienced by barcodes and decrease quickly, but the initial hurdle remains fairly high at this point (enabler 2).

8. Acknowledging Likely Unforeseen Impacts: Preparing for Radical Innovation
A new technology provides the opportunity to innovate. For many it could be an opportunity to leap ahead of their competition and many times its "real" benefits might be too "radical" to see upfront. Barcodes were initially seen as a means for automating supermarket checkouts but their "real" value was information creation. This idea was highlighted in an article by Fortune magazine in 2004. Following is a quote from the magazine article, "As sometimes happens with seemingly minor technological changes, bar codes have had a huge and unexpected impact. Previously, cash registers had been mere repositories of money; post-UPC, they became data conduits. Each time a product is sold, a record of the item is now preserved. This altered the balance of power between retailers and manufacturers. Once, manufacturers controlled data about product sales via warehouse inventories. They knew more about the products that were selling than the retailers. But, with UPC barcode adoption, stores now had data too—and both sides would learn to mine that information." (Varchaver 2004)
In the context of RFID technology, it is an infrastructure type technology (Curtin, Kauffman & Riggins, 2007) or a platform innovation that mandates future follow-on investments and significant changes in the routines and practices of organizations to realize benefits. *"Smaller organizations see RFID as an opportunity to make two leaps at once and hence displace some of the existing organizations. For us, in terms of retail checkout at this point it is not a major change, as it does not fundamentally change the business process. But going into the future, when there is item level tagging, and automated checkouts, it may be a paradigm shift because it eliminates the basis of our business. We may have to kiss our scanning and retail business goodbye"* according to the interviewee from organization J. As is also true with most infrastructure type innovations such as electricity, it has a much broader impact potential where significant strategic benefits would come more from how the technology is applied. This would mean making significant changes for the organizations and acquiring new knowledge about the innovation and its application in the business settings.
In RFID adoption one must modify business processes to leverage the benefits over barcode and other automated identification technologies. These processes will include inter-organizational processes as well if organizations want to enable real-time insight at a granular level. In this sense adoption of RFID may be characterized as disruptive or radical as it brings about changes in structure and functioning of the organizational entity and its inter-organizational systems. RFID

program manager from a logistics and transportation company C mentioned the dilemma that his organization is facing. According to him, *"RFID would require altering our existing optical scanners infrastructure and processes currently in place. A lot of learning, major changes in infrastructure may be required. This would be disruptive for the organization."*

To realize these inter-organizational benefits from RFID adoption, synergies need to be built between organizations collaborating at some level (enabler 5), and they need to be prepared for the unforeseen process impacts RFID implementation may require.

5. CONCLUSION

RFID presently exists in an early stage of maturation as far as commercial applications and adoption are concerned. We identified eight enablers for RFID adoption extrapolated from the successful maturation and adoption of barcode technologies and supported by data from interviews. We present these enablers as guides for those interested in implementing and innovating using RFID technology.

6. REFERENCES

Antonelli, C. (1994). "Localized technological change and the evolution of standards as economic institutions" Information Economics and Policy, 6, 195-216.

Besen, Stanley M. and Joseph Farrell. (1994). "Choosing How to Compete: Strategies and Tactics in Standardization, Journal of Economic Perspectives, vol. 8, no. 2, pp. 117-131.

Brown, Stephen A. (1997). "Revolution at the Checkout Counter", Harvard University Press, Cambridge, MA

Curtin, J., Kauffman, R.J. & Riggins, F.J. (2007). "Making the 'MOST' out of RFID Technology: A research agenda for the study of the adoption, usage and impact of RFID", Information Technology and Management, Vol: 8 (2)

Haberman Alan L. (2001). "Twenty Five Years Behind Bars", *Harvard University Press*, Cambridge, MA

Katz M. and Shapiro C. (1986). "Technology adoption in the presence of network externalities," *Journal of Political Economy,* vol. 94, no. 4, pp. 822-841

Krippendorff (1980). Content Analysis: An Intro. to Methodology, *Sage Publication*, Newbury Park, CA.

LaMoreaux Robert D. (1998). "Bar Codes and other Automatic Identification Systems", *Pira International*, Surrey, UK

3.

Markus Lynne M. (1987). "Toward a "Critical Mass Theory of Interactive Media" *Communication Research*, Vol. 14, No. 5, 491-511

Riggins F., Kriebel C. and Mukhopadhyay T. (1994). "The Growth of Interorganizational Systems in the Presence of Network Externalities" *Management Science*, 40(8)

UCC Website: http://www.uc-council.org

Van de Ven, A. H., and Garud, R. (1989). "The co-evolution of technical and institutional events in the development of an innovation", in J. Baum and J. Singh (eds), Evolutionary Dynamics of Organizations, pp425-443

Varchaver N. (2004). Fortune Magazine Website: http://money.cnn.com/magazines/fortune/fortune_archive/2004/05/31/370719/

Yang, G. and Jarvenpaa, S.L. (2005). "Trust and Radio Frequency Identification (RFID) Adoption within an Alliance." In R. Sprague (Ed.), Proceedings of the 38th Hawaii International Conference on Systems Science Big Island, HI

Appendix

Table 1. Bar Code Adoption Timeline	
Year	**Key Events**
1949	Invention of Barcodes
1952	Patent issued
1966	First commercial Application of Bar Codes
1969	Grocery manufacturers and retail associations perceive a need to develop a standardized bar code or UPC code
1970	Grocery Industry Ad Hoc committee formed for developing standards
1973	UCC adopts common standards on UPC
1974	UPC bar code used for the first time when 10 Pack of Wrigley's gum scanned
1976	Slow adoption prompts the business week article "The scanner that failed"
1978	Grocery introduces UPC
1983	Grocery completes adoption
1986	Retailers Wal-Mart and Kmart adopt UPC. Other retailers follow
1991	Wal-Mart mandates case level barcodes UCC128 by July 1992. Other retailers follow

Table 2. RFID Adoption Timeline

1940s	RFID technology invented by Harry Stockman	RFID used in WWII to distinguish friendly and foe aircraft		
1950s	D. B Harris patents radio transmission systems w/ modularly passive responder			
1960s	Commercialization of Electronic Article Surveillance			
1970s	Additional patents granted; RFID reaches consumer packaged goods	LASL releases RFID to public sector	Aimtech and Identromex formed	First implantable RFID tags used in dairy cows in Europe
1980s		Shift from performance to cost and size reduction		
1990s	Auto-ID Centre established at MIT	Los Angeles adopts pet tagging	Railroads begin use of RFID to track trains and cargo in motion	RFID-chipped Speed pass wand introduced; Gillette, P&G, UCC begin study of RFID use in theft prevention
2000s	Research and Development, Military and Government, Commercial Applications	Study of RFID use in supply chain expands from 3 to 70 corporate participants	P&G/Wal-Mart test of RFID tags for functionality w/in supply chain	Wal-Mart and DOD Mandates; Associated Foods Stores use RFID to track trailers

Table 3: Profile of organizations interviewed and their adoption and integration decisions

Note: * indicates those organizations that are not end users hence their responses on adoption and integration were not considered

Organization	Industry Sector	Main Supply Chain Role	RFID Adoption Role(s)	Initial Adoption	Expected Integration
A	Home Construction & equipment retailer	Retailer	End user	No	No
B	Consulting*	Solution providers	Provide expertise in RFID adoption		
C	Logistics and transportation	Logistics Support and Solution Provider	Expertise and End user	No	No
D	Label Makers And Antenna makers	Logistics	Vendors and End users	Yes	Yes
E	Reader Manufacturers*	Technology and solution providers	Vendors		
F	Beverage bottling	Suppliers	End User	Yes	No
G	Consumer products (paper based)	Suppliers	End User	Yes	Yes
H	Pallets	Suppliers	End User	Yes	Yes
I	Hardware,* software expertise	Consulting/ Solution Providers	Vendor		
J	Retail Solutions	Solution providers/manufacturing	End User	Yes	Yes

Table 4. RFID Adoption Enablers				
#	**Enabler**	**Bar Codes**	**RFID**	**Organization(s) Mentioning Enabler**
1	Standards	Consensus on Standards reached in (1973)	EPC Global Gen 2 Standards	A, B, C, D, E, G, H, I, J
2	Network effects and critical mass	Mass merchandisers adopt (1985-86)	Not yet but needed to drive tag prices down further	A, B, C, D, G, H, I, J
3	Mandates	Walmart (1991)	Walmart (2003)	A, B, C, D, E, F, G, H, I, J
4	Focus on innovation opportunity	Suppliers for grocery chains (Mid 1970's)	Suppliers for Walmart	B, C, G, H, I, J
5	Partner collaboration	Grocery Industry	Some level with Walmart but need better understanding of partner needs	B, G, I
6	Supporting Technologies	Laser and computers	Middleware and Supporting Hardware needed	B, C, D, I, J
7	Addressing consumer concerns	Consumer groups protest removal of price tags (1974)	Privacy concerns and protests on tagging	B, D,
8	Radical Innovation	Information Impact on Balance of power	Disruptive with the ability to leap frog competition and requires significant changes in business processes	A, B, C, D, E, F, G, H, I