Barriers to RFID Adoption

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Abstract

This paper proposes a theoretical framework to examine managerial, technological and societal obstacles to RFID innovation adoption. Technological obstacles include the issues of barcode replacement, applications scope and standards incompatibility. Managerial obstacles include the power structure and trust between business partners, as well as economic issues. Societal obstacles include legal and privacy issues. Our findings suggest demand- and supply-side perspectives of innovation adopted to remove technological and managerial obstacles. The collaborative effort among government, business and the public is imperative to remove societal obstacles. Adopting these socio-technical manifestos can effectively accelerate RFID innovation diffusion.

1. Introduction

The history of Radio Frequency Identification (RFID) goes back more than sixty years, its business applications started in the 1970s. The industry has never achieved a critical mass of adoption at the item level after thirty years of development. Some forecast that it could take another 10-20 years in hospitals [10], and other industries to reach widespread item-level adoption. The contradictory views about the potential contribution of RFID and its slow adoption poses a theoretical and practical research agenda to understand "why" and "how" to shorten the lead-time for the mass adoption.

2. Socio-Technological Perspectives

An organization needs to recognize three major groups of obstacles are ahead of RFID's reaching critical mass in its adoption curve: technological, managerial and societal. Technological obstacles encompass the technological capabilities, standards interoperability, as well as application scope. These issues contribute to the differences among companies in the perceived ease of use and perceived usefulness of RFID. Managerial obstacles deal with RFID adoption issues between business partners and customers. The power structure, trust and economic issues are major elements contributing to managerial obstacles. Societal issues, posed by individual consumers and supported by local and national governments, center primarily on invasion of privacy issues.

A typical innovation diffusion, such as for RFID, would be expected to follow in Roger's innovation diffusion process model in the following sequence: (1) agenda setting, (2) matching, (3) decision, (4) redefining/restructuring, (5) clarifying, and (6) routinizing [18]. An organization needs to move through the stages in an orderly and systematic way. For instance, an organization needs to understand RFID technology and its applications. However, knowledge about the technology alone is not sufficient because RFID has interorganizational impacts. As such, an organization also needs to have knowledge about its relationship with its customers and suppliers. Having this knowledge would help an organization become aware of the technology capability of RFID, and lead to the implementation stage. The initial acceptance of RFID will provide an organization usage experience to compare with its expectation. The gap between expectation and confirmed experience will either positively or negatively influence an organization's decision to continue or abandon adopting RFID.

RFID adoption is currently in the agenda setting phase. The need is to identify the potential obstacles that would negate or delay adoption. We show two groups of obstacles, or barriers: technology and managerial. In theory, these obstacles can be evaluated, and resolved, prior to the decision to adopt the innovation. We show societal issues along the entire length of the adoption cycle, because these issues may continue to arise as new or unanticipated problems arise during the adoption sequence.

In a survey on the readiness of a company to implement RFID technology, Russ [19] found that only 15.4% of companies planned to do so within a year. RFID experts have discussed copious reasons for its slow adoption. Major reasons include: (1) more expensive than bar codes, (2) lacking standards to interoperate between tags and data readers, (3) quality assurance problems, (4) untested scalability, [25], (5) 80-90% of reading accuracy rate, (6) lower accuracy rate at item level than at case or pallet level [3], (7) massive amounts of data generation (100 times more information than bar codes), and (8) many integration issues with the backend systems [21]. A review of these problems can help identify obstacles of RFID adoption. The understanding can help propose an effective strategy to improve the RFID diffusion process.

3. Technological Obstacles

3.1 Technological Capabilities

The barcode does not have the data storage capacity to provide continuous tracking and tracing capability. Many business problems originated from these weaknesses: counterfeiting, out-of-stock, and information invisibility. RFID is the anticipated alternative to bar codes. Expectations are that RFID technology will be superior to bar code technology at some point in the future, although it does not yet equal bar codes in read rates and read accuracy and reliability.

In a 2004 RFID conference in Baltimore, large-scale companies, such as Boeing, Cisco, Michelin, USDA and the Defense Department were enthusiastic about the commercial use of RFID to improve their competitiveness and accountability. RFID seems to have the potential to be superior to bar codes in its technical capabilities (e.g. read many times and different objects at the same time, with a higher tolerance of harsh conditions, and better security control). However, these promises are not yet reality. Questions remain. How do we handle objects that vary in shape, composition (liquid vs. powder vs. solid) and size? How far along the supply chain can a company go with RFID – fabrication, assembly, distribution, retail and consumer? Will RFID interfere with barcodes during the parallel implementation? How long a time horizon is required to test the reliability of RFID for different applications? How long will it take to develop common global standards?

3.2 Standards Interoperability

RFID needs at least three key components to operate: RFID reader, antenna, and middleware software. RFID antenna activates the RFID tag and transfers data by emitting wireless pulses at a given frequency. A reader reads the frequency. A station includes an RFID reader and an antenna. The reader can read information stored into the RFID tag and update this RFID tag with new information. The station is also responsible for communicating with the backend systems. Middleware software helps to configure the station and backend systems. Adopters can anticipate a significant and complex configuration process to synchronize data among business partners. The number of partners and their dissimilar systems can complicate the configuration process.

RFID readers and tags vary in their consistency at reading objects at different granularity levels and in different forms of objects. The standards variation has limited the scalability and application scopes. Standards interoperability issues occur in front-end and back-end. The incompatibility between readers and tags are front-end issues. The incompatibility between information stored in RFID stations and information stored in the existing system across supply chains are back-end issues.

3.3 Front-end Interoperability

RFID uses the frequency range from 125KHz to 13.65 MHz. There are four tag types based on its consumed frequency. The lower the frequency used to communicate, the lower the data rate obtainable. At low frequencies, the size of tag and readers are larger and suitable for attachment to large objects, such as vehicles or pallets. On the other hand, a RFID tag using a higher frequency has a higher data rate and a smaller size. This kind of RFID is more suitable for small objects, such as item-level objects, such as sweaters or a hammer. A reader designed to receive a specific range of frequency is incapable of receiving signals at a different frequency range. Differences in frequencies, coupling modes, communication and power sources result in data incompatibility issues [20]. RFID's front-end incompatibility raises the level of business challenge because the data could have incompatibility in its lowest granularity level. Feeding the inconsistent data into the backend systems across the supply chain can entail the poor quality of decision-making process.

3.4 Back-end Interoperability

RFID can generate at least ten times the amount of data generated by barcodes. It is crucial to build a secure and reliable network ecosystem to process the data collected via RFID and move them across thousands of companies in an integrated supply chain [11]. However, how to process the huge amount of data on a real-time basis to support business decisions between business partners is an unprecedented challenge. Three key layers of applications account for the back-end interoperability: (1) middleware, (2) integration layer, and (3) enterprise applications. For middleware layer applications, RFID tags read different signal frequencies at various locations in the front-end. Data collected via different RFID tags have different formats because data are encoded differently with respect to syntax and semantics (error and flow control). Data in different formats need to be standardized and integrated before they can be fed into back-end applications for further processing. The integration layer applications are to cleanse the collected data. Vendors like IBM, Hewlett-Packard Co., and Sun's OATSystems Inc. are some vendors to provide the integration solution.

Companies across a supply chain adopt various systems at different managerial levels to process data in numerous ways to support their business operation. Data integration is a challenge when disparate information systems of business partners are incompatible with each other. This mandates the inter-cooperation of business partners through a system integration life cycle, including adoption decision, acquisition, implementation, use and maintenance, evolution and retirement phases [4].

3.5 Scope Applications

Companies did not seriously consider business applications of RFID until recently. RFID provides

tracking and tracing (pedigree) features that help a company know the physical location and quality of an object within the supply chain during its lifetime. The potential of applying RFID to combat the sale of counterfeit drugs drew the attention of the pharmaceutical industry and government regulatory agencies. About $9.6 to $15.4 billion worldwide trade per year in pharmaceuticals are counterfeits. Meta Group predicted the use of RFID by drug makers would surpass that of consumer packaged goods companies within 18 months [27]. The pharmaceutical industry is not alone in enthusiastically pursuing the innovative applications of RFID. Other industries include, but not limited to, railways, airports, shipping & cargo, bus transit, hospital, retailer and manufacturer, have assimilated RFID to address their respective business issues.

4. Managerial Obstacles

In addition to the technical obstacles, managerial issues like power structure, trust and economic issues could influence the network effects of RFID adoption. Many of the top 100 Wal-Mart suppliers considered RFID investment a waste of their money according to a 2004 AMR study [16]. The low degree of enthusiastic cooperation from the suppliers of Wal-Mart is a visible case to substantiate the importance of managerial issues.

Inter-Organizational Relationships (IORs) include strategic alliance, partnership, joint venture, delegation, research & development consortium and many networked organizations [17]. Like Electronic Data Interchange, RFID is another alternative technology to assist the physical and information flows of an IOS. RFID can potentially create new and useful information, and improve information sharing and transparency between business partners.

The resource dependency theory of Pfeffer and Salanzick [13] is applicable to the explanation of RFID implementation. This theory asserts that interorganizational dependence is created when one business partner "does not entirely control all of the conditions necessary for the achievement of an action or for obtaining the outcome desired from the action" [13]. To lower cost or improve operational efficiency through the sharing of a greater volume of sensitive information, RFID applications require that buyers and suppliers need to form a stronger IOS than barcode applications. This includes the willingness of both parties to share information, and collaborate. For instance, how willingly and how much trust do the suppliers – P&G and its competitors – have in sharing their company's information with Wal-Mart?

From the theoretical perspectives of core competencies and the resource-based view of firms [7][1], a business partner needs to reduce the degree of interdependence, thereby, minimizing the uncertainty of reliance on business partners for important resources. In accordance with this theory, the power structure between business partners is highly correlated with the degree of interdependence and its balance, which is determined by who has the control of key resources. Large enterprises favor RFID because it can potentially increase the dependence of their suppliers on them. On the other hand, suppliers are afraid of losing their control to their customer and could resist the new technology.

The RFID implementation process requires the institutionalization of agreed-upon standards (EPCGlobal, HDMA or others), business practices, information to be shared, and the invested equipment and human resources. These requirements can substantially affect the allocation of key resources that can determine the interdependent relationship. Three key factors of an alliance -- power, trust, and economics -- influence the decision of an organization to adopt RFID.

4.1 Power Structure

Hart and Saunders [8] asserted that a set of mechanisms should be deployed—ranging from convincing power to compulsory power—to influence the power of an organization to adopt an interorganizational system (IOS). To realize the abovementioned benefits, RFID needs to be used as an IOS to support business operations. As such, these two kinds of power mechanisms are important for the consideration of RFID adoption.

The convincing power mechanism focuses on reward and incentive approaches to encourage an organization to adopt RFID; this is useful to maintain a long-term alliance relationship. In contrast, the compulsory power mechanism, like punishment, is often used when an organization has many partners and helps influence business partners with a relatively low bargaining power to implement RFID.

When one party has a higher convincing power to influence its business partners to adopt RFID, it can influence the perceived benefit of implementing RFID for business partners. This pressure will help convince business partners to implement RFID. The convincing power of a business partner correlates with an organization's perceived benefits versus the actual cost of RFID implementation. An organization is more likely and willing to implement RFID when there are high benefits and low costs. [14].

Firms with dominating power over its business partners—such as the ability to penalize business partners by reducing or canceling orders—are more likely to force the use of interorganizational systems. Iacovou, Benbasat and Dexter [9] suggested a firm use compulsory power to pressure business partners to comply with its policy. The more bargaining power a firm has over its business partners, the higher the possibility that organization can obtain resources from its business partners. This unbalanced relationship will force companies to maintain a cooperative relationship and make them more receptive to the adoption of RFID.

Premkumar et al. [14] studied the IOS and found that when firms have a higher willingness to implement IOS, their degree of involvement will increase. This increased

involvement will result in the funneling of increased capital and human resource to integrate a successful IOS.

4.2 Trust

Trust is another important factor influencing the interorganizational relationship [23]. Hart and Saunders [8] asserted that once an organization adopted an IOS, it would decide to extend its use based on the degree of trust by business partners. That is, when the degree of integration between business partners is increased, business partners can access information that was not previously available or was inaccessible. Nidumolu [12] found that trust in business partners could encourage the willingness of an organization to be open for negotiation and share information. Like any IOS, trust is also an important factor for the success of RFID. Trusting organizations are more willing to invest in RFID and share information with their business partners. Moreover, trust can stop opportunist behavior from appearing. When the opportunists' behavior declines, the opportunity to share information with business partners will improve.

When business partners propose adopting RFID to facilitate their transaction, an organization trusting its partners is more likely to reach consensus in terms of the benefits they can realize with RFID. An organization may also think it is worthwhile to invest in RFID because of trusting its partners.

An organization needs to face many security challenges of RFID to an interorganizational relationship. The first challenge is information sharing between business partners. A mega retailer such as Wal-Mart has many suppliers. Some of them are competitors, like Procter & Gamble, and Kimberly-Clark. Having these two suppliers adopt the same RFID standard could increase the chances for indiscriminate flow of sensitive information and create distrust and tension between competitors.

4.3 Economic Issues

There are many hidden costs associated with the early adoption stage of RFID. These costs not only include tags and readers, but also middleware, consulting, R&D, consulting fees, system changes, maintenance, training, testing and conversion from barcode to RFID, service by third party service providers, and achieving integration across the supply chain. The concept of total cost of ownership could provide a clear picture of the cost associated with RFID investment.

According to a survey of Yankee Group [5], RFID spending falls into four categories: hardware (29%), software (27%), internal labor (23%), and consulting services (21%) with a total cost ranging from US$ 9 to 25 million for a large-scale manufacturer in the consumer goods industry [22]. Steve Banker, a senior director for SCM at the ARC Advisory Group, surveyed 24 companies actively implementing RFID and found it takes a minimum of 10 years to see a positive ROI on a $10 million RFID investment [10]. This slow return on investment is a major reason why companies are hesitant to adopt RFID.

Most of the successful applications of RFID occurred when the cost of the RFID tag was insignificant when compared with the cost of the tagged item, such as a truck or a locomotive. RFID tag cost becomes much more of a concern when the cost of the item being tagged is lower, such as in clothing, or groceries.

5. Societal Obstacles

RFID tags can store at least ten times more information than the barcode. Sensitive and identifying information, such as names, SSN, credit cards and medical history, can be stored in a tiny RFID tag. Some unique information (e.g. unique object number) stored on a RFID tag cannot be removed and is accessible by default. A sensitive tag reader can read information from a victim's tag hundreds of feet away. This poses serious privacy issues.

Advocates argue the benefits of RFID outweigh privacy issues. RFID can record every move of a prisoner and keep an eye on guards in prisoner applications. In the hospital, RFID can help management retrieve patients' medical record faster and monitor a residential patient in case of collapse or accident. RFID can also help in locating kidnap victims. For commercial uses, Wal-Mart tried to achieve the real-time tracking, and more effectively manage its supply chain. The FDA supported pharmaceutical companies to fight drug-counterfeiting problems with RFID. The U.S. government advocates using RFID chips on passports to fight against terrorists.

Despite these potential benefits, many companies are interested in obtaining the information for commercial usage. For instance, an insurance company would be interested in knowing the health history of its client in order to adjust the insurance coverage for its clients to increase profit. Retailers may potentially misuse the information by tracking their customers' buying habits for marketing purpose. According to a survey, 63% of consumers who are aware of RFID are concerned about invasion of privacy. Further, 88% of those consumers believe that government is the most likely organization to abuse consumer privacy rights with RFID, followed by banks, insurance companies, and credit card companies [24]. California State Senator Debra Bowen proposed a new bill to curtail the use of RFID tags to track consumers in order to protect consumer privacy. Although legislators did not approve the bill, it shows the importance of addressing privacy issues related to RFID.

6. Recommendation

RFID has the potential to be superior to bar codes for data collection and processing; however, it is being more slowly adopted than many advocates would like. How can the rate of adoption be accelerated? Rogers [18] offers some insight into how innovations diffuse and some of the keys to successful adoption.

Innovation theory is primarily concerned with the

acceptance of innovation. Technological, societal and managerial obstacles are barricading RFID acceptance. Bass [2] defined mathematically the new product failure as the lower rate of followership than that rate of innovative adoption. RFID currently falls into the situation. Attention needs to be drawn to accelerating the acceptance rate of followers.

A manifesto to resolve the acceptance issue can come from two institutional perspectives: supply-side and demand-side. Supply-side theory asserts that an inventor's creativity and initiatives are the prerequisite to the successful diffusion of a technological innovation [26]. Increasing the motivation of followers to implement RFID initiatives can promote the diffusion. Demand-side theory asserted that who accepted the innovation and why they accepted it are important requisites for innovation diffusion [15]. Minimizing the resistance to RFID adoption is more useful than promoting the motivation of RFID adoption from the demand-side perspective. Different strategies are pertinent to accelerate RFID adoption from supply- and demand-side perspectives.

6.1 Supply-side

Roger's innovation diffusion theory provides the supply-side perspective. Bounded rationality and the issue of time lag are two underlying assumptions of the theory. Most companies have been rationally weighing the benefits and cost of the RFID adoption in the traditional economic sense. The analysis of managerial and technological obstacles indicated that companies at the current stage put more emphases on economic issues than on power structure, trust, and technological issues. Two acceptable resolutions are available to resolve the debacle: (1) narrow the scope of RFID applications and (2) improve the awareness of RFID usefulness. Executable strategies for the first resolution include pilot testing, experimenting objects with a higher readability and reliability, adopting phased development approach, and selectively adopting a RFID standard. Effective strategies to execute the second resolution are as follows: creating transparent communication channels [6], training users to improve their knowledge and skills in using RFID, avoiding an overly formal communication structure between RFID project team, users, and upper-level management, giving pioneers (including internal employees and external consultants) slack resources to make the early phased project right, providing explicit support of upper-level management and publicizing positive implementation results, and exercising certain compulsory power to convince smaller suppliers to adopt RFID.

6.2 Demand-side

Diffusion theory asserted that a newer innovation would replace the current technology when it becomes outdated and inefficient. This is not the case for RFID. Barcodes are providing a well-accepted and effective technology application. Consequently, there is no urgency to replace barcodes with RFID despite its promised returns in other applications. Minimizing the degree of resistance to the replacement decision is an organizational priority from the demand-side perspective. Two feasible solutions can overcome the hurdle from the demand-side perspective.

Institutionalize RFID diffusion strategies for organizations based on their adopter categories. Adopter in different categories needs to adopt different strategies to minimize resistance. RFID is currently in the first two stages. Strategies pertinent to these two stages are:

Innovators: Creating the resistance to barcode can promote RFID diffusion among innovators. When major buyers become early innovators, they can join efforts to reduce further efforts to promote the use of barcodes. This strategy can help not only improve the perceived benefits and costs of RFID adoption, but also reduce the expanded use of barcode. This will contribute to the increased number of innovators and followers.

Early adopters: Sidestep resistance by clearly convincing users that RFID is much superior to barcode in technological and business arenas. The standards convergence and best practices can help strengthen the convincing power, thereby lowering the resistance to switching to RFID from barcode technology. They can also reallocate resources from barcode to RFID efforts. Users with abundant resources in barcode technology are more likely to resist RFID adoption. The existing barcode users will gradually move towards the RFID adoption after the resources reallocation.

6.1 Societal Issues

The misuse of RFID could generate a great degree of public distrust. However, societal issues are less of a concern at this stage because the public has not been experiencing the incidence of privacy intrusion. Some preventive measures are available to gain the trust of public when adopting the technology: The first measure is to educate the public on the realities of RFID continuously. The second is to improve the security mechanisms of RFID to garner the trust from the public. Third, it may be necessary for government agencies to establish some control over the RFID applications that are acceptable. As a corollary to regulation, there should be a mechanism to punish violators of established guidelines, whether imposed within the user community or the regulatory community. The public has a right to believe that the technology they use, or that is used by the companies with whom they do business, is non-threatening, or at least they are warned of the possible consequences, such as with warning labels on medications.

7. Conclusion

Businesses in different industries are facing different pressures from technological, managerial and societal obstacles. To gain greater insight into the RFID adoption process, we showed how innovation decision-making and interorganizational theories could help explain how an organization needs to adopt different strategies to overcome these obstacles based on its own unique

situation. We took the institutional viewpoint of an innovation to propose a series of strategies from the supply- and demand-side perspectives. The supply-side perspective is to promote the motivation of RFID adoption. The demand-side perspective is to reduce the resistance and social irritant during the RFID adoption process. An organization needs to confront the obstacles that are most likely to adversely them and develop strategies to overcome these obstacles at the most appropriate time.

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