

A Comparative Analysis of RFID Adoption in Retail and Manufacturing Sectors

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Abstract— Radio Frequency Identification (RFID) technology mandates by large retailers and various government agencies has driven compliance requirements for many organizations to implement the technology. In this paper, we use content analysis methodology and examine open literature, news releases, industry white papers, and published journal and conference articles to identify and compare current implementation status, adoption drivers, potential benefits, supply chain activities, applicable tasks, and challenges of implementing RFID in the retail and manufacturing sectors. Our analysis concluded that whereas RFID applicable tasks for retail and manufacturing sectors are significantly different, the adoption drivers, benefits, supply chain activities, and challenges are similar.

Indexed Terms—RFID, technology adoption, retail, manufacturing

I. INTRODUCTION

Radio Frequency Identification (RFID) is an emerging technology that enables contact-less and wireless information access via radio waves for identifying, capturing, and transmitting information from tagged objects to enterprise systems. RFID technology was primarily invented for automatic data capture and is often referred as a tracking and tracing technology. Leading companies from a variety of industries have adopted RFID to enhance security and visibility across the myriad of their operations. Two key features that separate RFID technology from its competing partners such as optical barcodes are non-line-of-sight tag reading and the ability to read multiple tags simultaneously from a longer distance. Recent advances in information and communication technologies, cost reduction in RFID readers and tags, and mandate compliance requirements by large retailers (e.g., Wal-Mart, Target, Albertson) and various government agencies (e.g., Department of Defense and Department of Homeland Security) are the primary forces behind the deployment of the technology.

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Although the general perception is that RFID technology has progressed significantly in the last decade due to accelerated development of sophisticated devices and software, determining accurate measures for RFID return on investment (ROI) still remains a critical and challenging task. The challenge is even more daunting for the manufacturing sector that bears a major upfront investment to satisfy their large retail customers as well as to meet government mandates. Consequently, identifying all potential benefits that manufacturers can achieve, and comparing them with those of the retail sector, both in the short and the long term contributes toward the development of ROI measures.

There have been several studies focused on investigating RFID implementation issues such as drivers, benefits, and challenges in retail and supply chains, little research has been directed to analyze these related issues across different sectors. In this paper, we focus on comparing various RFID implementation issues across retail and manufacturing operations. The main objective is to see whether there are significant similarities or differences in terms of these factors across the two sectors. This will allow us to develop better implementation strategies by tailoring them to the specific requirements and nature of each sector, eventually leading to better appreciation, utilization, and adoption of the technology across different applicable tasks and supply chain activities. Results from this research can help avoid the pitfalls of looking at implementation issues from a single perspective and thus failing to satisfy other important stakeholders. We believe this is a necessity for wider adoption of the technology.

In this research, we have considered both general issues as well as, retail, and manufacturing specific issues. Our guiding research question for this study is “What are the similarities and differences in RFID implementation between retail and manufacturing in terms of adoption drivers, potential benefits, key applicable tasks, relevant supply chain activities, and challenges?” We focus on the retail and manufacturing sectors primarily because these are the key sectors investing in RFID technology either due to the benefits that may be gained from implementing the technology or to meet mandate requirements. We have also observed some contradictory facts, which motivated us to delve deeper into the issues to establish less obvious underlying relationships and facts. For instance, Frost & Sullivan [1] reported that the revenue in the RFID retail market was \$400.2 million in 2004, and expected to grow to \$4,169 million by 2011. On the other hand, according to a recent survey sponsored by NCR [2], 9% of participating retailers have an RFID implementation timeline

as compared to 44% of participating manufacturers. This indicates that the retail sector is not adopting the RFID technology as rapidly as expected and that the concept of biggest portion of the benefit pie for retailers might be just a misconception.

In this work, we attempt to broaden the research horizon by including press releases and industry white papers that include actual RFID implementation project results (both pilot and large-scale implementation projects) in addition to journal or conference papers. We have primarily included consumer packaged goods (CPG) and apparel retailers and manufacturers of CPG products, automotives, and chemicals in our study. This is mainly governed by the availability of data. In addition, we looked at retail and manufacturing operations across their supply chains to better capture the varied potential of RFID to influence these sectors.

Our paper is organized as follows. We present and discuss background and related work in Section II. In Section III, we describe the research methodology, followed by a discussion of the salient results in Section IV and finally conclusion and implications in section V.

II. BACKGROUND AND RELATED WORK

In this section, we summarize some key studies that have contributed to promote the overall awareness among businesses models of the RFID technology and its applications.

Karkkainen [3] analyzed the benefits of RFID and concluded that the technology leads to increased supply chain efficiency for short shelf life products. Larsson and Qviberg [4] also conducted similar research on the justification of RFID implementation in a specific furniture retail industry. Jones *et al.* [5] discussed potential benefits and challenges of RFID throughout the supply chain for retailers in United Kingdom (UK). Angeles [6] argued that RFID technology has the potential to provide process freedom (thus reducing labor requirements) and real-time visibility across the supply chain especially in retailing and logistics. Bose and Pal [7] claimed that the significant benefits achieved from implementing RFID technology are improved visibility across the supply chain and full or semi- automation of rote operations. Schuster *et al.* [8] claimed that Auto-ID technologies like RFID would allow new level of inter-connectivity among businesses by improving supply chain data flow through mass serialization and granularity of data.

Prater and Frazier [9] examined the impact of RFID technology on electronic supply chains and specifically in grocery retailing. Their work focused on the market drivers leading to RFID implementation in grocery retailing. Michael and McCathie [10] attempted to identify the pros and cons of RFID in supply chain management. However, their work is geared toward RFID adoption in general whereas our major focus in this paper is to look at the retail and manufacturing sectors specifically. Koh, Kim and Kim [11] surveyed on the

issues and critical factors of RFID adoption in the retail sector; but their focus on perceived benefits alone may be limiting due to the emerging nature of the RFID technology. Vijayaraman and Osyk [12] conducted an empirical study on RFID implementation in the warehousing operation and concluded that positive ROI is the most significant challenge undermining RFID adoption. Bhattacharya *et al.* [13] conducted a study on RFID implementation issues, specifically for the retail sector. They identified key drivers, potential benefits, challenges, applicable tasks, and significant supply chain locations for RFID implementation in retail sector. They concluded that potential benefits are strongly related to RFID applicable tasks but not with specific supply chain activities.

As can be seen from the above review, most studies focus on retail sector. There has been no study comparing issues across different sectors. In addition, the issues of where can RFID be used and what kind of tasks can RFID be applied have somewhat been ignored in most of the earlier studies. Our goal is to provide an in-depth analysis of the technology in the context of the two major players in supply chain that have heavily been influenced by RFID either directly or indirectly.

III. RESEARCH METHODOLOGY

We use a research methodology called *content analysis* to guide our data collection, analysis, and interpretation. Content analysis has been widely used in informatics, library science, and social science research [14].

The methodology is exploratory, yet allows researchers to capture and quantify information based upon the presence of words or concepts within a set of text and is suitable for studying an emerging technology adoption. Our study consists of three major phases:

(1) *References identification and search*: In this phase, we identify the possible sources as the targets for our extensive search for relevant references. Our search covers popular on-line sources such as AIM Global, RFID Exchange, RFID Gazette, RFID Journal, RFID Solutions Online, and major academic on-line databases such as ABI INFORM, ACM Digital library, Elsevier ScienceDirect, IEEE Explore, and Springer-Verlag. We use keywords starting with "RFID" and collect all relevant articles. We conducted our search for articles from October 2006 to July 2007. Articles published after July 2007 have not been included in our study and are beyond the scope of this work. A total of 686 relevant articles were found and retrieved. Out of the 686 references, there are 40 published journal articles, 40 conference proceedings, 79 academic magazines, 4 academic theses, 191 industry white papers, and 332 news releases. The majority of these articles were published anywhere between the year 2002 and 2007. Please note that the news releases contributed to the potential benefits construct mostly.

(2) *Association analysis*: We categorize and sort the data based upon the major themes that emerged, from which, we then develop an integrated conceptual framework to guide

our in-depth analyses. Figure 1 shows a conceptual framework with the key issues that emerged from our association analyses and classification, which include drivers, benefits, supply chain activities, applicable tasks, and challenges.

(3) *Data analysis and interpretation*: Based upon the conceptual framework that we developed, we then use it to organize and perform in-depth analyses. We examined and kept track of the frequency of the articles that support each aspect of the framework that acts as an important quantitative measure to support the analysis and discussion.

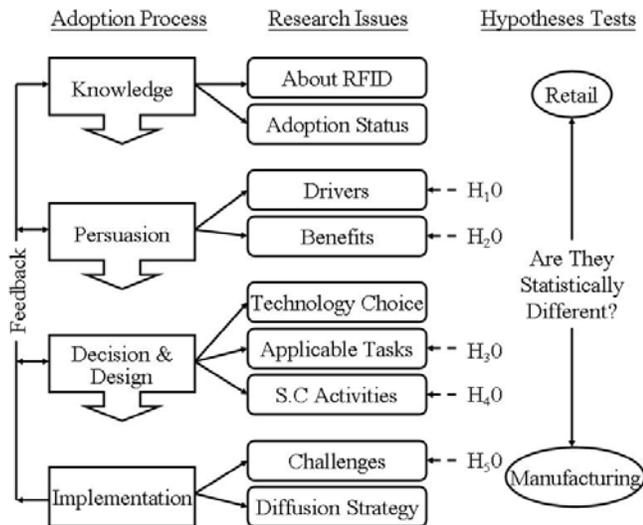


Fig. 1. Research framework

IV. RESULTS AND DISCUSSION

A. Status of the RFID Adoption

The retail sector is the second largest sector in terms of the number of employees as well as the number of business establishments in the United States [15]. Manufacturing represents about 10.8 percent of all employment in US, yet less than 5 percent of all establishments. Retailers have recognized great potential of using RFID technology in order to stay competitive and achieve profitability in the short as well as the long term [16]. With increasing globalization, companies are facing more and more competition, which is forcing them struggle harder and harder to succeed through better performance [11]. According to IDTechEx [17], the retail sector will comprise 44% of the global RFID market value for systems including tags by the year 2016. According to another survey of worldwide companies conducted by retail market research company, Retail Systems Alert Group [18], the RFID adoption rate, once fueled primarily by retail mandates, is now being led by voluntary manufacturer implementations. However, while it is believed that, the technology will bring great benefits to retailers; manufacturers will bear most of the costs and see little return [19]. Considering this negative, dominant view, it is very important to delve deep and compare the benefits across the

two sectors. We believe that there is immense potential for increased RFID ROI in the manufacturing and retail sectors that has been ignored previously. This will eventually contribute to wider adoption of RFID technology in general as well as within these particular sectors.

B. Major Drivers for RFID Adoption

We have identified six important drivers for RFID adoption in retail and manufacturing sectors. Table I shows the frequency and the significance of the proportional hypothesis test for each driver. The proportional hypothesis tests measure the contribution of each of the drivers to the total. As shown, benefits obtained from implementing the RFID technology emerged to be the dominant driving force for adopting the technology compared to meeting mandates required by large retailers and government. The other important drivers for RFID adoption include technology drivers and anti-counterfeiting. Mandate compliance for manufacturing includes legal and government regulations along with large retailer mandates whereas for retail, giant retailer mandates is the primary driver. In addition, increasing knowledge about RFID technology seems to have some positive impact on RFID adoption for manufacturers. This trend is not observed for retail. Although we must admit that, we cannot make any strong arguments about this trend at this stage because of the very low frequency that supports it. However, this is an interesting observation which when properly explored can boost technology adoption but needs further exploration. From table 1 we can observe that overall the adoption drivers for the two sectors are similar.

TABLE I: DRIVERS FOR RFID ADOPTION

Drivers	Retail	Manufacturing
Benefits	338 (91.60%) 0.000*	446 (91.02%) 0.000*
Mandates/compliance	19 (5.15%) 1.000	32 (6.25%) 1.000
Decreasing cost of tags and readers	5 (1.36%) 1.000	3 (0.59%) 1.000
EPC Global initiatives for standardization	51(0.36%) 1.000	6 (1.17%) 1.000
Increasing knowledge about RFID	N/A	1 (0.20%) 1.000
Anti-counterfeiting	2 (0.54%) 1.000	4 (0.78%) 1.000
Total	369	512

* Statistically significant

We also conducted a one-way analysis of variance to test whether the two groups statistically differ from each other in terms of adoption drivers. Our null hypothesis is:

$$H1_0: \mu_{\text{retail (drivers)}} = \mu_{\text{manufacturing (drivers)}}$$

The calculated p-value is 0.914 (greater than 0.05) and thus we cannot reject $H1_0$ and conclude that the adoption drivers for the two sectors are not different statistically. However, the importance of complying with government and legal regulations apart from retail mandates and the seemingly

positive influence of the maturity of the technology on manufacturing sector makes it a little different from retail and deserves specific attention.

C. Benefits of Adopting RFID

From Table II, we can see that most of the benefit categories obtained from implementing RFID in the manufacturing sector are similar to those of the retail. The main difference is in the order of the importance of the benefits. The most significant benefits for manufacturing include operational efficiency (p-value = 0), improved visibility (p-value = 0), better management of inventory, and reduced cost. In contrast, better management of inventory is the most significant benefit for retail (p-value = 0), followed by improved security (p-value = 0.017), and improved operational efficiency (p-value = 0.067), with the rest not significant.

TABLE II: BENEFITS FROM RFID IMPLEMENTATION

Benefits	Retail	Manufacturing
Better Management of Inventory	77 (22.87%)	46 (9.87%)
Improved Security	56 (16.57%)	27 (5.79%)
Improved Operational Efficiency	52 (15.38%)	154 (33.05%)
Increased Visibility	45 (13.31%)	148 (31.76%)
Reduced Cost	37 (10.95%)	39 (8.37%)
Better Information Accuracy	31 (9.17%)	32 (6.867%)
Improved Customer Service Levels	29 (8.58%)	16 (3.43%)
Increased Sales	11 (3.25%)	4 (0.86%)
Total	338	466

* Statistically significant

From our analysis, we observe that improved operational efficiency and improved visibility have the potential to affect manufacturing operations more than retail operations. Both retail and manufacturing operations refer to the range of operations across their supply chains. A wider range of sub categories of benefits contributing to operational efficiency emerged for the manufacturing sector than in comparison to retail. Using RFID to achieve leaner manufacturing, improve worker productivity, and to reduce errors and rework emerged to be more important for manufacturing than for retail. Improved production planning, improved quality control, and achieving equipment reliability through RFID usage improves manufacturing operations and throughput specifically. These possibilities are manufacturing specific and can provide value over time. Better inventory management is a more significant benefit for retail than in comparison to manufacturing. Improved security has a very low priority for manufacturing unlike retail. Also improved customer service levels and increased sales are more significant for the retailers. Reduced cost and better information accuracy are of equal importance to both sectors.

Many of the benefits discussed above have the potential to influence each other and thus we should not overlook their

dependence. For example, improved security as a significant benefit obtained from RFID, undermines the negative aspects of the privacy issue, because security and privacy are negatively correlated. Negative correlation between the two refers to the fact that one needs to be compromised for the other so that a reasonable balance between the two can be found. The privacy issue for retail sector originates from concerns at the consumer end.

We also used the one-way analysis of variance to test how the two groups statistically differ from each other in terms of potential RFID benefits. Our null hypothesis is:

$$H2_0: \mu_{\text{retail (benefits)}} = \mu_{\text{manufacturing (benefits)}}$$

The calculated p-value is 0.478 (greater than 0.05) and thus we cannot reject H2₀ and conclude that the potential benefits for the two groups are statistically not different. However, we must note that the distribution of the benefits across the two sectors is quite different as it appears from the raw frequency data.

D. Technology Choice

Two fundamental decisions in RFID adoption concern choosing the appropriate radio frequency and tag type. Factors such as, user requirements, product contents (water, metal), application type, reading distance, security concerns, and environmental factors (e.g., noise, vibration, moving speed, and magnetic sources) determine these decisions. Among these, product content and application type are the major factors for making the decision.

TABLE III: TECHNOLOGY CHOICE

Device	Retail	Manufacturing
UHF reader	25 (89%)	66 (80%)
HF reader	3 (11%)	13 (16%)
LF reader	0 (0%)	3 (4%)
Total	28	82
Passive tags	15 (94%)	29 (70%)
Active tags	1 (6%)	12 (30%)
Total	16	41

Our study indicates that UHF is the dominant frequency used by both retail and manufacturing sectors. Around 80% of the articles mentioned use of UHF as the dominant frequency in both retail and manufacturing. Only 11% of the articles claim HF as the retail choice whereas 16% of the articles claimed the use of HF in manufacturing sector. None of the articles mentioned LF or microwave frequency being used in retail sector whereas about 4% mentioned LF being used in manufacturing sector (See Table III). This indicates that there is a potential of HF to gain popularity within the manufacturing sector. However, this analysis also shows that there are plenty of manufacturing operations where UHF could be used. Basically, both UHF and other lower frequencies are being used hand in hand within manufacturing sector for various tasks.

Tags can be classified into four types - passive, active, semi-passive, and semi-active – according to the availability

of power and how they communicate. The selection of tag type has also been influenced by several factors, for example, cost, read/write capability, size/weight, memory, tag life, power source, and read distance. Among these, cost, write capability, and power source are the key selection factors. According to our statistics, the passive tag is the dominant tag type used in retail, about 94%. The other 6% of applications claimed to use active tags. For manufacturing sector, 70% of the articles claimed to use passive tags and around 30% of the articles claimed to use active tags. Thus, we can say that active tags are more widely used in manufacturing sector than in comparison to their retail counterpart. This shows that active tags have huge potential to improve manufacturing operations. The sample size of this data is too small to warrant an in-depth statistical analysis.

E. Which RFID Applicable Tasks can be used?

We have identified eight broad tasks to which RFID can be applied in retail and manufacturing. These tasks are briefly discussed below:

- *Inventory management*: It refers to controlling activities with the purpose of getting the right inventory, in the right place, at the right time, in the right quantity, and at the right cost. The purpose is to avoid stock outs and to reduce excess inventory.
- *Tracking and tracing*: It refers to the identification of products across their movement through the supply chain. In our analysis, it also pertains to tracking temperature and pressure when appropriate.
- *Security against theft/fraud*: It refers to protection from theft or fraud.
- *Automated shipping/receiving*: It refers to faster shipping and receiving of tagged products that does not need manual intervention for identification of products.
- *Automated manufacturing*: It refers to assistance with the automation of mass customized production processes through better handling movement of parts.
- *Returns/Recalls management*: It refers to better and faster handling of returns and recalls of products.
- *Asset management*: It refers to securing and tracking assets automatically as they move through facility for their better utilization.
- *Acquire business intelligence*: It refers to better demand planning and improved collaboration based on real time business information acquisition.
- *Tracking shopping behavior*: It refers to obtaining information about consumer behavior and their reactions to products.

Table IV shows that tracking and tracing, inventory management, automated shipping/receiving are the most significant RFID applicable tasks. One important observation in our analysis is that the manufacturing sector does not focus on applicable tasks as much as retail. The lower frequency corresponding to tasks is evidence supporting this argument.

This table shows that the manufacturing sector does not tie potential RFID benefits and applicable tasks together which is a necessity for better RFID implementation strategies. This could be a reason for more uncertainty about the technology in this sector. For wider adoption of the technology in manufacturing sector increasing awareness about which tasks to focus is a necessary step.

TABLE IV: RFID APPLICABLE TASKS USED

Applicable Tasks	Retail	Manufacturing
Inventory management	173 (21.31%) 0.000*	45 (23.81%) 0.000*
Tracking and tracing	161 (19.83%) 0.000*	83 (43.92%) 0.000*
Security against theft/fraud	133 (16.38%) 0.001*	4 (2.12%) 1.000
Automated shipping/receiving	96 (11.82%) 0.735	20 (10.58%) 0.817
Automated manufacturing	N/A	11 (5.82%) 0.999
Returns/recall management	71 (8.74%) 1.000	11 (5.82%) 0.999
Asset management	70 (8.62%) 1.000	10 (5.29%) 1.000
Acquire business intelligence	67 (8.25%) 1.000	5 (2.65%) 1.000
Tracking shopping behavior	41 (5.05%) 1.000	N/A
Total	812	189

* Statistically significant

From our analysis, we also observed that tracking and tracing is of more importance for manufacturing than for retail. Manufacturers can track raw materials as well as finished products, which could allow maintaining just in time inventory and lead to leaner manufacturing processes eventually leading to savings. Tracking temperature for certain products across the supply chain is also included within the tracking and tracing application task and is observed to be of importance for both manufacturers and retailers. However, we did not consider this as a separate applicable task in our study. In addition, automated manufacturing that could be achieved through RFID implementation is a benefit specific to manufacturing sector. Inventory management is a significant task for both the sectors. Security against theft/fraud is a much more important task for retail. Automated shipping/receiving is of close importance to both sectors. Recall management, asset management, and acquiring business intelligence are of a little more importance to retail than for manufacturing. Considering the manufacturing operations environment and their business relationships with multiple suppliers and retailers these two tasks can be significantly improved with RFID usage and be of immense value to manufacturers. Tracking shopping behavior is a task of specific interest to retailers.

We also conducted a one-way analysis of variance to test whether the two groups statistically differ from each other in terms of RFID applicable tasks. Our null hypothesis is:

$$H3o: \mu_{\text{retail (tasks)}} = \mu_{\text{manufacturing (tasks)}}$$

The calculated p-value is 0.001 (less than 0.05) and thus we can reject H_0 and conclude that the RFID applicable tasks for the two sectors are statistically different. However, we must note this result could be biased because of small sample size and needs further clarification through empirical investigation. Our preliminary analysis shows difference in applicable tasks, which demands more research in this area to identify the reasons for such difference. This could boost RFID adoption rates significantly.

F. What Supply Chain Activities are Influenced by RFID?

Most of the major industries today see immense potential of the RFID technology to better integrate their supply chain that can improve their efficiency and cut down overall cost of operations significantly. Benefits of RFID such as improved operational efficiency, improved security, improved visibility, and better information accuracy primarily revolve around allowing for improved supply chain management. Improved visibility, which is a significant benefit for both retail and manufacturing, helps to achieve tightly integrated supply chain. We analyzed the two sectors in terms of the supply chain activities that they are more inclined to using the RFID technology. We observed that the overall frequency corresponding to the supply chain activities in manufacturing is significantly lower than that of retail.

Table V shows the dominant supply chain activities for the two sectors. Each of the activities is briefly explained below [14]:

1. *Merchandise planning*: It is an approach aimed at maximizing ROI through proper planning of *sales and inventory*. This approach is all about maintaining a balance between sales and inventory in order to increase profitability.
2. *Assortment Planning*: It is the retailers' planning for selection of merchandise both in terms of depth and breadth (e.g., what and how much).
3. *Sales planning*: It is a business process to plan the routes to reach the target customers.
4. *Price management*: It is the process of understanding, managing, and improving pricing processes based on predictions and forecast data. It has direct impacts on profit.
5. *Promotion planning*: It is the process of planning and managing promotions that drives demand and profit. It also depends on forecast data.
6. *Production planning*: It is the process of making decisions on the proper utilization of resources to fulfill customer demands in an efficient manner.
7. *Replenish, allocation and scheduling*: It is the process to replenish products to avoid out-of-stock situation. It has the potential to reduce inventory and influence improved customer services.

8. *Warehouse management*: It is the process to achieve improved distribution of products across diverse facilities. It has the potential to reduce inventory.
9. *Distribution*: It is the process of distribution of products accurately to the correct destination.
10. *In-store operation*: Management of various store operations like receiving, shelf stocking, product ordering for store replenishment so on and so forth
11. *Sales*: Managing the 'sales' process which is directly associated with revenue generation.
12. *Return*: Managing return merchandise. The idea is to make reverse logistics streamlined.

TABLE V: RFID APPLICABLE SUPPLY CHAIN ACTIVITIES

Supply Chain Activities	Retail	Manufacturing
Replenish, Allocation and Scheduling	208 (39.54%) 0.000*	14 (13.21%) 0.094
Warehouse Management	99 (18.82%) 0.000*	22 (20.75%) 0.000*
In-store Operations	82 (15.59%) 0.000*	N/A
Returns / Recalls	74 (14.07%) 0.002*	20 (18.87%) 0.001*
Distribution	32 (6.08%) 0.999	8 (7.55%) 0.748
Merchandise Planning	19 (3.61%) 1.000	N/A
Promotion Planning	6 (1.14%) 1.000	4 (3.77%) 0.988
Production planning	N/A	38 (35.85%) 0.000*
Price Management	5(0.95%) 1.000	N/A
Sales Planning	1 (0.19%) 1.000	N/A
Assortment Planning	1 (0.19%) 1.000	N/A
Total	526	106

*Statistically significant

As can be seen from Table V that warehouse management and returns/recalls are the two activities that are significant for both retail and manufacturing. Replenishment is a much more significant activity for retailers than it is for the manufacturing sector. Production planning is a more manufacturing specific supply chain activity whereas in-store operations, price management, merchandise planning, and sales planning are the retail specific significant supply chain activities where RFID is used.

We also conducted an analysis of variance to test whether retail and manufacturing statistically differ from each other in terms of supply chain activities of interest. Our null hypothesis is:

$$H4o: \mu_{\text{retail (SC)}} = \mu_{\text{manufacturing (SC)}}$$

The calculated p-value is 0.068 (greater than 0.05) and thus we cannot reject H_4o and conclude that the supply chain activities for the two industries are not different statistically. However, we must note that the overall frequency corresponding to the supply chain activities of manufacturing is much smaller than in comparison to that of retail. This

indicates that the retail sector better ties up the supply chain activities with the expected benefits. In addition, the use of RFID is much well spread across the different activities of the supply chain for the retail sector.

G. Challenges in Adopting RFID

From table VI, we can see that most of the challenges for RFID implementation are generic in nature and are not specific to a particular domain. However, lack of standards and data warehousing issues are not as important for manufacturing as in comparison to retail.

TABLE VI: CHALLENGES OF RFID IMPLEMENTATION

Challenges	Retail	Manufacturing
Privacy Issues	36 (38.71%) 0.000*	N/A
High Cost	16 (17.20%) 0.115	19 (45.24%) 0.000*
Standard Issues	14 (15.05%) 0.27	6 (14.29%) 0.431
Data Warehousing and Integration	13 (13.98%) 0.378	2 (4.76%) 0.974
Technical Issues	6 (6.45%) 0.981	9 (21.43%) 0.072
Business Process Redesign	3 (3.23%) 1.000	2 (4.76%) 0.974
Employee reluctance	3 (3.23%) 1.000	1 (2.38%) 0.996
Multiple Frequencies	2 (2.15%) 1.000	N/A
ROI Unclear	N/A	2 (4.76%) 0.974
Unequal benefits among Industries	N/A	1 (2.38%) 0.996
Total	93	42

* Statistically significant

From our analysis, privacy emerges to be the most dominant challenge that needs to be addressed before RFID can penetrate deeper into the business world for the retail sector. However, it is not at all a concern for manufacturers, which is intuitive as such, because manufacturing does not face to consumer directly. High cost is a little more concern for manufacturing as they need to bear most upfront costs of implementing the technology but the difference is not too much unlike expected which is a positive indication in itself. Data integration issues are also daunting as the amount of data generated by the typical RFID system is enormous and business processes need to be redesigned to generate useful information from the data. However, data integration issue is a more significant challenge for retailers. This could be an indication that the manufacturing sector is not thinking in terms of long-term benefits achieved by integrating RFID with their legacy systems to get useful information that will affect their business processes. Employee reluctance to change is a challenge that is of similar significance to both sectors.

In addition, multiple radio frequencies existent seems not to be a concern for manufacturing sector. Unclear return on investment (ROI) and unequal benefits among industries based on type of products is a concern for manufacturing.

Very low frequencies supporting these observations make them untenable to some extent but could be potential pointers for further exploration.

We can see that challenges are also somewhat related to each other like benefits. With technological advancements, most of these challenges will eventually be overcome. However, being a societal issue, privacy requires more than technological advancement and will remain a major challenge for retailers. A balance between the benefits consumers can get in terms of better service and savings and the impingement on privacy should be a top priority of retail sector.

We used the one-way analysis of variance test to see whether the retail and manufacturing statistically differ from each other in terms of RFID adoption challenges. Our null hypothesis is:

$$H_0: \mu_{\text{retail (challenges)}} = \mu_{\text{manufacturing (challenges)}}$$

The calculated p-value is 0.232 (greater than 0.05) and thus we cannot reject H_0 and conclude that the potential benefits for the two sectors are not different statistically. However, we must note that the distribution of some of the challenges across the two sectors is different as it appears from the raw frequency data. In addition, some challenges are specific to each sector.

H. RFID Diffusion Strategy

Technology diffusion can be either initiated from top executives and pushing down to the users for a broader application or demanded from the users and seeking administrative for support [20] [21]. The 'Top down' is the traditional model where administrative mandates introduce the technology and administrative decisions and perceptions drive adoption and diffusion, as, for example, in the adoption of the Internet. 'Bottom up' is the model in which the diffusion of the technology is primarily dependent on the perceptions and decisions of individual users, as in the case of 'wireless technology'.

The process of RFID technology diffusion in any organization currently appears to be top down, as it is primarily mandated and pushed by top managers and executives. Because of the newness of the technology, we would expect the current technology diffusion process to be top down irrespective of the type of industry. However, this could change with the maturity of the technology. For automotive, chemical, and high priced electronic goods manufacturing companies, looking at the possibilities of benefits obtained from using RFID in their operations and because high cost is not a very big concern for them, and the fact that errors, and rework are significantly reduced the diffusion model might change in future.

Another interesting issue related to the RFID technology adoption/diffusion model is whether RFID will follow the common technology/innovation decision process:

knowledge, persuasion, decision, and confirmation [21]. Though the technology is still in its infancy it would be interesting to see what path or course it will follow in the end. It will be even more interesting to see if the paths will be different for the retail and manufacturing sectors (or for any other category) considering the initial push of the technology has been from government and retail mandates for manufacturing so far.

RFID is an emerging wireless technology in which benefits grow with adoption as with the Internet. Most early RFID adopters incur high costs in their RFID implementation; however, with growing and more adoption, the costs of RFID devices will quickly diminish, and that will lead to more benefits and further adoption [22]. This should be true regardless of the industry type.

V. CONCLUSIONS AND IMPLICATIONS

In this paper, we analyzed and compared the status, drivers, benefits, applicable tasks, relevant supply chain activities, and challenges for adopting RFID in retail and manufacturing sector. We use analysis of variance and proportional hypothesis tests on the frequency data for our analysis. Table VII summarizes the results of the analysis of variance tests.

TABLE VII: SUMMARY OF HYPOTHESIS TESTS

Hypothesis	P-Value	Result
H1o: Retail and manufacturing adoption drivers are not different.	0.914	Cannot reject
H2o: Retail and manufacturing potential benefits are not different.	0.478	Cannot reject
H3o: Retail and manufacturing applicable tasks are not different.	0.001	Reject
H4o: Retail and manufacturing supply chain activities are not different.	0.068	Cannot reject
H5o: Retail and manufacturing challenges are not different.	0.232	Cannot reject

We conclude that adoption drivers and potential benefits for both sectors are not different statistically. However, improved operational efficiency and improved visibility came up to be more important for manufacturing than for retail. A wider range of sub-categories of benefits contributing to improved operational efficiency emerged for manufacturing than for retail. This shows immense potential and possibilities of RFID technology in manufacturing that needs to be explored. Improved inventory management and improved security emerged to be more important for retail than for manufacturing. Although the potential benefits across the two sectors are similar, the order and the distributions of the potential benefits differ. Many of these benefit categories are also strongly correlated with each other that needs to be considered when quantifying the ROI expected from implementing this new technology.

We also conclude that retail and manufacturing RFID applicable tasks are statistically different. Little focus on

tasks within the manufacturing sector was observed during our analysis. This indicates that there is not enough knowledge about what tasks to focus to expect certain benefits in the manufacturing domain. Increasing awareness about established correlations among the tasks and potential benefits can aid in making better strategic implementation decisions. In addition, the supply chain activities for which RFID is used are not statistically different for both the sectors. However, the p-value (0.068) measuring their similarity is very close to the critical value 0.05 that is an indication of some difference in the two sectors in this perspective. We observe that the retail sector uses RFID more widely than manufacturing across the supply chain. Most of the challenges impeding diffusion of the technology by businesses emerged to be generic from our analysis with a few exceptions. Overall, the challenges came out to be not different statistically for the two sectors.

This research contributes toward clarifying some of the uncertainties associated with the RFID technology, uncertainties impeding its progress and acceptance in the business world despite its immense potential. We chose two important players in the RFID market and compared across various issues. Interestingly from our analysis, it appears that there is a lot of scope for manufacturing sector in terms of gaining from RFID implementation unlike the popular belief of the technology being more valuable to the retailers. This comparative analysis has provided insights about the technology. We intend to carry this work forward and validate or revise our model by putting it to test in the real world. We shall design a survey instrument based on our present analysis and field-test it. In addition, we want to develop correlation maps of tasks, and supply chain activities with potential benefits aiding in strategic decision-making. We also intend to develop a computational model from our comparative analysis and use simulation to transform the benefits to dollar values for the specific sector.

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