Evaluating Variance in Cost-Benefit Perceptions of RFID Systems in the Supply Chain Sector

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Abstract

Since the introduction of Radio Frequency Identification (RFID) systems, retailers such as Wal-Mart have pushed their suppliers for adoption. The Cost-Benefit justification for retailers is more direct and stronger than it is for other supply chain sectors, especially manufacturers, who bear the cost of affixing tags. Their cost-benefit scenario improves if the technology can be used to streamline the manufacturing process. Prior studies have noted this imbalance in the costs and benefits between Supply Chain entities, and even conducted case studies to examine specific industries. No studies were found to attempt to capture the comparative perceptions of the costs and benefits across the supply chain echelons. This paper therefore attempts to explore and understand the variance in perceived costs and benefits for the use of RFID systems by managers of organizations on different echelons of the supply chain. The study is based on 210 responses to a validated instrument used in prior research on novel information technology.

1. Introduction

It has been established that RFID is a significant innovation for supply chain organizations [1, 2]. Prior research has examined the RFID innovation from different a variety of perspectives with respect to the supply chain. This has included propositions of research agendas [3, 4], best practices and implementation plans [5-8], adoption theories [9, 10], benefits and potential [5, 11-13], technical challenges [14-16], security and privacy issues, [17, 18], discussions on return on investments [19-22].

Cost appears to a key factor in the adoption of RFID systems. This has been discussed in general purview of supply chain organizations, and case studies have examined areas of higher returns on investment for a specific supply chain sector [23]. However, as of the time of this research, no studies were found to examine the variance in perceptions of cost-benefit across supply chain echelons, and the characteristics of these issues. Our research, therefore, aims to understand these differentials in cost-benefit perceptions, and the causes of the variance, while adopting the RFID innovation. In order to provide a deeper understanding of the causes of the variance, we break down the dimensions of cost-benefit to study its perceptions for each dimension as held by supply chain echelons.

The paper begins with discussing extant literature on discussions on RFID, supply chain and cost-benefit perceptions. The next section describes how the research was conducted; followed by results, their discussion and conclusion.

2. Literature Review

Adoption of any new innovation in industry is not done without an assessment of the benefits provided by it. Therefore cost-benefit of RFID has been a well discussed topic. For instance, a search for the terms “cost benefit” in the RFID Journal publication yielded over 900 articles about it, dating to as far back as 2003 [24]. Academic studies have discussed costs [19, 22], benefits and capabilities [5, 11], return on investments for RFID systems [20, 25], as well as issues and challenges [26-29]. There have been several case studies that examine cost and associated benefits of in specific sectors, such as retail [30]. For instance, Uhrich notes that RFID has been finding multiple applications in the retail sector, albeit not all related to supply chain operations [31]. Fosso and Chatfield use a case study to support that a first step in this direction is achieved by identifying tangible and intangible costs that are associated with different levels of the expected benefits each organization wants to realize [32]. However, different supply chain organizations have different functions for the use of RFID technology; correspondingly their perceptions of RFID can be expected to differ.

2.1 The Supply Chain and its Echelons

The Council of Supply Chain Management Professionals (CSCMP) defines the Supply Chain as a system of organizations, their people and activities involved with the transfer of products and services from suppliers to consumers [33]. According to Mentzer et al [34], a supply chain is defined as “a set of three or more entities directly involved in the upstream and downstream flows of products,
services, finances and information from a source to a
customer”. Although these can be assumed of
researchers, they are defined here briefly for the sake
of clarity [33, 34]). These sectors comprise: (i)
Manufacturing: use of raw materials or components
to create/assemble products. (ii) Distribution:
facilitate flow of goods from a supplier organization
to another towards the end user. (iii) Wholesale:
broker bulk shipments of merchandise, and bear
parallels with Distribution. (iv) Transportation:
movement of goods from one location to another,
factory to wholesaler, wholesaler to retailer, etc. (v)
Third Party Logistics (3PL): provide an integrated
and customized operation of warehousing and
transportation. According to CSCMP, concurrent 3PL
organizations may take on a variety of bundled
logistical activities such as transportation,
warehousing, inventory management, packaging,
freight forwarding, etc. (vi) Retail: resell supplied
products to a consumer.

At its most basic level the supply chain can be
characterized as having three functions: the
creation/supply of goods and products, their
transport, and finally consumption that occurs at the
retail end of the supply chain [34]. For the sake of
clarity, we will refer to these as echelons of supply
china. Although all supply chain organizations have
the same overall function (i.e. that of transporting
products from to the customer), they accomplish
radically different roles in that process. As a result
the RFID innovation plays a varied role in its
applicability, functionality, costs and benefits. For
instance, manufacturers often bear the burden of
affixing tags to their outgoing products at the case or
pallet level, without seeing benefits of the
functionalities that the innovation imparts. Trade and
industry publications have been discussing costs of
RFID technology for years, but there only been few
studies that explored perceptions of cost-benefit and
none that examined it from the perspective of supply
chain industry sectors.

2.2 Organizational Size

Prior research has suggested that adoption of
novel information technology can be affected by the
size of the focal organization [35]. Lee and Lee
assert that large organizations such as the US
Department of Defense, Wal-Mart, and Tesco have
implemented mandates that have driven RFID
implementations in their respective supply chains
[30]. For the supply chain partners, however, RFID
projects compete with other information technology
projects for scarce resources. RFID implementations
require a significant up-front investment in both
hardware and software [19, 36]. It seems reasonable,
then, to consider that larger organizations have more
resources at their disposal and might therefore have a
different perception of the costs vs. the benefits of
this new technology [37]. Moreover, given the
prevailing economic uncertainty, a smaller firm may
take a “wait and see” attitude, unwilling to risk their
more limited resources until the benefits (vs. the cost)
of this new technology have been more firmly
established in their particular supply chain context.
Although supply chain sector is the focus of this
study, rather than organizational size, the size of the
firm and its relationship to available resources make
it a relevant variable in the research model, regardless
of the supply chain sector in question. Therefore in
Organizational Size is included in analysis as a
control variable in this research.

2.3 Cost-Benefit

While the benefits of IT innovations are novel,
the costs of adopting them are typically similar [32].
Premkumar and Roberts [35] examined the impact of
cost versus benefit of four information technologies
in small businesses. They considered three core
aspects of cost: the cost of adoption of the
innovation, the cost of maintenance and updates for
the innovation, and the cost of training employees to
use the innovation. Their research showed that cost
versus the benefit impression varied by the
technology being considered. These three costs
represent different elements of the cost of adoption of
an IT innovation. For the RFID innovation, cost
appears to have been an issue since 2003 when Wal-
Mart mandated their top 100 suppliers tag their
pallets with EPC Gen 2 tags [38] RFID tags. Since
then there have been several discussions about costs
of implementation of RFID systems and the issues
that validate these cost components [39]. To measure
the perception of cost versus benefits, we used the
validated instrument from the study by Premkumar
and Roberts. In addition to their three items, we
included one item to measure an “overall” impression
of the cost-benefit tradeoff. Therefore the current
research addresses perceptions of (i) cost-benefit of
adoption, (ii) cost-benefit of maintenance and support
(iii) cost-benefit of training employee, and (iv) the
overall cost-benefit.

The case of RFID is interesting, because the
costs of RFID (in relation to information technology
products examined earlier) are high [19], as are the
potential benefits [40]. Since the nature of the
distribution of cost-benefit value is unknown, we use
an exploratory approach to uncover the relationships
between cost-benefit perceptions and supply chain
echelons. Therefore, our research asks the following
open ended questions about the perceptions of cost versus benefit between sectors.
1. What, in general, are the perceptions of cost versus benefit for the RFID innovation by different supply chain groups?
2. Are there differences in perceptions of cost-benefit for the RFID innovation between the different echelons of the supply chain?

3. Methodology

As the research questions seek to explore the perceptions of supply chain managers, the methodology selected was a cross-sectional online survey. The target respondents were a dataset of 2900 practicing supply chain managers who were members of the Council of Supply Chain Management Professionals (CSCMP), a premier professional organization for individuals involved in supply chain management. Respondents of the survey held titles such as President, CEO, COO, Vice President, Manager, Director, Associate Director, Superintendent, and Supervisor. The survey comprised an item to collect supply chain sector(s) that the respondent belongs to, perceptions of the costs versus benefits of RFID using the aforementioned validated instrument Premkumar et al.[35] on a five point Likert scale, and a question on organizational size that was operationalized as number of employees, in addition to relevant demographic information. The average age of the survey respondents was 47 with average tenure at their company at 10.1 years. The respondents were highly educated, with 91% possessing at least a 4-yr college degree, and almost half of those possessing a graduate degree.

After removing responses with missing fields, the data sample contained 210 responses, for a response rate of 7.2%. In order to assess non-response bias, the sample was split into four quartiles based on the time stamp of the response. The first twenty-five percent of responders, i.e. the “early responders,” were compared against the last twenty-five percent, i.e. the “late responders” using t-tests. There were no significant mean differences in organization size (p=0.59), respondent age (p=0.97), respondent’s tenure within the organization (p=0.34), or a randomly selected survey item (p = 0.30), suggesting that nonresponse bias is not a significant issue. Many organizations play multiple supply chain roles, the survey allowed organizations to check more than one supply chain sector. Table 1 below displays the breakdown by count and percentage. Also, the survey included “Other” as a choice in order to prevent forced membership into a supply chain sector.

For the purpose of evaluating the variance of the perceptions of cost-benefit perceptions for RFID technology, we grouped the supply chain organizations into four groups concurrent with Mentzer’s characterization of the fundamental supply chain.

<table>
<thead>
<tr>
<th>Table 1. Industry Sectors in Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry Sector</td>
</tr>
<tr>
<td>Manufacturing</td>
</tr>
<tr>
<td>Distribution</td>
</tr>
<tr>
<td>Third Party Logistics</td>
</tr>
<tr>
<td>Retail</td>
</tr>
<tr>
<td>Transportation</td>
</tr>
<tr>
<td>Wholesale</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>TOTAL</td>
</tr>
</tbody>
</table>

* Total count exceeds 210 since some organizations were in multiple industry sectors

The first group was comprised organizations that were identified solely as manufacturers (N =63). Their primary function involves creation of the product, without involvement in distribution and delivery. The second group (N =48) included respondents who identified their firms as manufacturers that also participate in the distribution and transportation of their products. This group is considered a hybrid of the manufacturing and transportation sectors. The third group (N= 68) included those firms that were identified as distribution, third party logistics, wholesale, and transportation, without manufacturing or direct retail, and were grouped as logistics, since their core function was moving the product downstream. The fourth group (N = 31) had the distinct function of selling and therefore only included those organizations that designated themselves solely as wholesalers and/or retailers in the survey.

4. Results and Discussion

The first research question asks about the general perception of cost-benefit with regards to the RFID innovation in the supply chain. As shown in Table 2, the means of the items used to measure Cost-Benefit were higher than three (neutral point between one and five) for three of the four items, therefore showing that, in general, the costs of RFID were perceived to be higher than the benefits. The highest cost was considered to be maintenance and support for RFID systems (Mean = 3.5). The lowest cost was perceived to be that of training employees (Mean = 2.98). Table 3 illustrates that with the exception of
the Training costs, these deviations from the neutral value are statistically significant.

**Table 2. General perceptions of cost-benefit**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adoption</td>
<td>3.39</td>
<td>1.08</td>
</tr>
<tr>
<td>Maintenance</td>
<td>3.50</td>
<td>0.95</td>
</tr>
<tr>
<td>Training</td>
<td>2.98</td>
<td>0.95</td>
</tr>
<tr>
<td>Overall</td>
<td>3.33</td>
<td>1.04</td>
</tr>
</tbody>
</table>

The second research question inquired about differences in Cost-Benefit perception between the Supply Chain groups. The analysis involved using SPSS 17.0 to perform MANCOVA, with the supply chain sectors and firm size as independent variables and the four cost-benefit constructs as dependent variables. MANCOVA was selected because it allows simultaneous analysis of multiple dependent variables with categorical independent variables, while partiailling out the effects of covariates. Organization size was included as a covariate in the analysis because it is expected to influence perceptions of cost. Smaller firms might reasonably be expected to have more limited access to resources required to implement new technologies.

Table 4 summarizes the results of the MANCOVA. We focus on the impact of our primary research concern, the supply chain sector. Regarding the costs of Maintenance and Training there is insufficient evidence of a significant difference in cost-benefit perception across supply chain sectors. Notably, organizational size and its interaction with sector are seen to have a significantly different perception of cost-benefit when it comes to cost-benefit perception across supply chain sectors. The analysis suggests, however, that the respondent’s supply chain sector does have a significant effect on perceptions of Overall cost-benefit (p < 0.01) for RFID technology, and in particular for the cost-benefit of Adoption (p < 0.10), beyond the effect of firm size. It is interesting to note that the cost of adoption is significantly higher than the cost of maintenance or training (p<.10), and is likely the biggest contributor to the perception of overall cost.

Table 5 summarizes the marginal means for the perception of Adoption and Overall cost-benefit, listed by supply chain sector. These means are calculated at the average value for firm size. According to our survey results, Manufacturers have a more negative perception of the cost of adopting RFID vs. the benefits from adoption. Surprisingly,

**Table 3. Perceptions of Cost vs. Benefits, deviation from neutral stance**

<table>
<thead>
<tr>
<th></th>
<th>t</th>
<th>p</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adoption</td>
<td>5.334</td>
<td>.000</td>
<td>.394</td>
</tr>
<tr>
<td>Maintenance</td>
<td>7.669</td>
<td>.000</td>
<td>.498</td>
</tr>
<tr>
<td>Training</td>
<td>-2.85</td>
<td>.776</td>
<td>-0.019</td>
</tr>
<tr>
<td>Overall</td>
<td>4.593</td>
<td>.000</td>
<td>.326</td>
</tr>
</tbody>
</table>

**Table 4. Summary of MANCOVA Results**

<table>
<thead>
<tr>
<th></th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adoption</td>
<td>1.448</td>
<td>.230</td>
</tr>
<tr>
<td>Maintenance</td>
<td>4.088</td>
<td>.045</td>
</tr>
<tr>
<td>Training</td>
<td>1.687</td>
<td>.196</td>
</tr>
<tr>
<td>Overall</td>
<td>5.245</td>
<td>.023</td>
</tr>
<tr>
<td>Sector</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adoption</td>
<td>2.189</td>
<td>.091</td>
</tr>
<tr>
<td>Maintenance</td>
<td>0.361</td>
<td>.781</td>
</tr>
<tr>
<td>Training</td>
<td>0.394</td>
<td>.757</td>
</tr>
<tr>
<td>Overall</td>
<td>5.313</td>
<td>.002</td>
</tr>
<tr>
<td>Sector * Size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adoption</td>
<td>2.148</td>
<td>.095</td>
</tr>
<tr>
<td>Maintenance</td>
<td>0.571</td>
<td>.635</td>
</tr>
<tr>
<td>Training</td>
<td>0.540</td>
<td>.656</td>
</tr>
<tr>
<td>Overall</td>
<td>3.809</td>
<td>.011</td>
</tr>
</tbody>
</table>

Logistics providers are not far behind in their negative perception of the cost vs. benefits of RFID Adoption.

As shown in Table 5, Manufacturers and Retailers both have more negative perceptions of the Overall cost-benefit situation than those firms involved in any way in the transportation and distribution of products.

**Table 5. Summary of Marginal Means**

<table>
<thead>
<tr>
<th></th>
<th>Sector</th>
<th>Mean</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adoption</td>
<td>Mfg</td>
<td>3.606</td>
<td>.134</td>
</tr>
<tr>
<td></td>
<td>Hybrid</td>
<td>3.269</td>
<td>.154</td>
</tr>
<tr>
<td></td>
<td>Logistics</td>
<td>3.456</td>
<td>.132</td>
</tr>
<tr>
<td></td>
<td>Retail</td>
<td>3.347</td>
<td>.196</td>
</tr>
<tr>
<td>Overall</td>
<td>Mfg</td>
<td>3.551</td>
<td>.128</td>
</tr>
<tr>
<td></td>
<td>Hybrid</td>
<td>3.289</td>
<td>.146</td>
</tr>
<tr>
<td></td>
<td>Logistics</td>
<td>3.208</td>
<td>.126</td>
</tr>
<tr>
<td></td>
<td>Retail</td>
<td>3.593</td>
<td>.186</td>
</tr>
</tbody>
</table>

Also of note is the fact (i) that manufacturers perceive the adoption costs to be higher than any
other echelon, and (ii) that the hybrid echelon that combines Manufacturers with Logistics perceives adoption costs to be lower than any other echelon.

5. Implications and Limitations

This study presents a preliminary overview of the perception of cost vs. benefit for adoption, maintenance, training, and overall implementation of RFID systems within supply chain sectors. We found that RFID providers have a challenge ahead in convincing their potential clients to adopt their information technology innovation. Moreover, we found that what should be a driving force behind adoption, industry members of the logistics and transportation sector, instead demonstrated a significantly negative perception of cost vs. benefit for this new technology.

The perception of overall high costs by manufacturers is expected, and can be alleviated by using a phased plan for implementation, shared governance of standards and costs, training routines, and budgeting expected costs and benefits [21]. According to Kumar et al. [41] manufacturers can improve synchronization with the supply chain, and integrate RFID technology better into their own facilities and software systems. Although retailers share the same sentiment of high overall costs and high training costs, their operations and needs are different. Relatively higher turnover automatically introduces higher training costs. However, item-level tagging was shown to increase the cost-benefit ratio by automating tracking and reducing the out-of-stock rate [30]. Ustundag [42] proposes a cost-sharing model to share tagging costs between the three supply chain echelons of retailer, distributor and manufacturer. Once RFID systems become more commonplace, experience and prevalence of with these systems will also come to be expected of all supply chain members. Further, as larger retailers such as Wal-Mart, Sam’s, Target, Nordstrom, BestBuy, and Dillards expand the use of RFID systems, the technology will become more mainstream and standardized, reducing overall costs.

Out study also uncovered functional areas in which the costs were perceived to be higher than the benefits. For instance, costs of adoption were considered to be high and justifiably so. An organization must not only to investigate its competitive strategy, but also needs to estimate the technological, operational and managerial advantages it will provide, before deciding to adopt. Further, it must organize a process around its pilot, assessment and subsequent adoption. Also noted from Table 5 was the fact that the organizations that were involved in manufacturing as well as the logistics function, considered adoption costs to be lower than other any other supply chain echelon, while at the same time, those dealing only manufacturing considered it to be the highest. This can be explained by the expectation of the ability to extend adoption costs, over multiple supply chain sector-functions (e.g. allowing for savings in training and maintenance costs) – lower corresponding scores for Sectors in Table 4, supports this notion.

Like all studies this paper also has some limitations. First, a cross-sectional survey can only provide a one-time snapshot of what is a rapidly evolving field. Second, organizational size was operationalized as number of employees. Some studies also consider revenue as an estimate of this component. Third, the cost-benefit can be expected to have other constructs/dimensions than what was used in this paper. Finally, this study does not take into consideration the industry sector for the respondent firms. High-value industries such as electronics might have different perceptions of cost-benefit than low-item-value industries.

6. References

[9] Jeyaraj, A., A. Sengupta, and V. Sethi. Stages in Adoption of RFID Innovations by Organizations: Identifying Facilitators and Inhibitors. in Fourteenth


7. Appendix

Survey items (Likert Scale, 1 = Strongly Disagree, 5 = Strongly Agree)

1. The cost of adoption of RFID technology is far greater than the benefits.
2. The cost of maintenance and support of RFID technology is very high for our business.
3. The amount of money and time invested in training employees to use RFID technology is very high.
4. Overall, the cost versus benefit for RFID technology is high.