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The Impact of RFID Utilization on Manufacturing Effectiveness and Efficiency within a Supply Chain Context

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Abstract

An RFID outcomes performance model is theorized. Data from a sample of 155 manufacturers was collected and the model was assessed following a structural equation methodology. Findings indicate that adoption of RFID technology within the manufacturing sector leads to improved manufacturing efficiency and manufacturing effectiveness. Improvements in efficiency lead directly to improved organizational performance, and improvements in effectiveness lead directly to improved supply chain performance. Results also indicate that improved supply chain performance positively impacts organizational performance.
1. Introduction

Technology advocates propose that adoption of RFID technology will lead to improved organizational and supply chain performance (Cannon, Reyes, Frazier, and Prater 2008; Murphy-Hoye, Lee, and Rice 2005; Angeles 2005; Asif and Mandviwalla 2005; Narsing 2005; Patterson, Grimm, and Corsi 2004; Srivastava 2004). Prime downstream supply chain customers such as Wal-Mart, Albertson's, Target, and the Department of Defense have begun requiring that their suppliers provide RFID enabled products (Ault 2007; Asif 2005; Kinsella 2005; McPartlin 2005). One problem this paper addresses is that many suppliers forced to adopt RFID by a downstream supply chain member see it as a cost of doing business rather than as an opportunity to tap data that could lead to effectiveness and efficiency gains. Other firms have begun to adopt RFID technology with the expectations that such adoption will lead to improved organizational and supply chain performance (Green, Whitten, and Inman 2008). These firms, like Boeing and Airbus, see it as a value-added technology with great potential to improve their supply chain operations (Reyes and Frazier 2007).

Green et al. (2008) found that RFID technology utilization directly impacts supply chain productivity and indirectly impacts organizational performance through supply chain productivity. The Green et al. (2008) study is exploratory in nature and incorporates relatively limited measures of supply chain and organizational performance. While they develop an initial measure of RFID-utilization, they do not discuss and incorporate a measure of RFID-outcomes within their model.

Recent empirical studies by Vijayaraman and Osyk (2006) and Reyes, Frazier, Prater, and Cannon (2007) were conducted in order to better understand reasons for implementing RFID along with the challenges implementing firms faced. Both studies used prior literature on
potential outcomes and reported a high percentage of respondents not considering RFID implementation. Among the reasons for not planning to use RFID were: not applicable to our business, lack of unforeseeable benefits, and cost. Both studies reported on reasons for deploying RFID (Vijayaraman and Osyk, 2006) and how the firms plan to use RFID tags (Reyes et al., 2007), with better inventory visibility and help automate inventory replenishment as the top reasons. The Vijayaraman and Osyk (2006) study found the top sources of RFID cost savings included reduction in out-of-stock, minimized inventory losses, and reduced labor costs due to less material handling. Reyes et al. (2007) report on realized improvements, such as accuracy and availability of information, levels of process automation, level of customer service, and labor cost.

The empirical studies by Angeles (2007) focused on consumer/shopper response to RFID product item tagging. Her study uses theories of procedural justice/fairness, expected utility and prior literature on personal privacy for its theoretical framework. The findings showed that some consumers responded positively to the procedural justice concept, whereas the less privacy-sensitive consumer valued the RFID benefits and are willing to pay more for the RFID tagged items for specific benefits like faster checkouts and fewer product stockouts.

Jarillo (1988) found that supply chains must first be effective to come into existence and then they must evolve to become efficient in order to survive. In effect, Jarillo (1988) believes that supply chain members must first be concerned with capabilities and if successful will then focus on the ability to produce low cost inputs and outputs. RFID technology is a supply chain infrastructure that first allows member to develop capabilities for becoming effective and then will create the ability to become efficient. A supply chain’s success is an attribute of transitioning and/or regeneration through activities that exhibit the characteristics of efficiency-
seeking and effectiveness-seeking (Mason-Jones, Naylor, and Towill 2000; Hofer and Schendel 1978) thus creating an environment for outcomes that are beneficial to supply chain members.

Green et al. (2008) surveyed large U.S. manufacturers and assessed an RFID utilization model that included RFID utilization, supply chain productivity, and financial performance of the organization as constructs. They theorized that RFID utilization would both directly and indirectly (through supply chain productivity) impact the financial performance of the organization. Their results supported the indirect but not the direct impact of RFID utilization. Building on the work of Green et al. (2008), it is our purpose to define and describe the RFID outcomes construct and to assess its role within an RFID performance model. To that end, we propose the following RFID Outcomes Performance Model (Figure 1). The model incorporates RFID utilization as antecedent to manufacturing efficiency and effectiveness outcomes, and supply chain performance and organizational performance as consequences. We theorize that adoption of RFID technology within the manufacturing sector will lead to improved manufacturing efficiency and manufacturing effectiveness which will, in turn, lead to improved organizational and supply chain performance. For example, manufacturers should realize improved levels of accuracy in raw materials, work-in-process, and finished goods inventory records. The discrepancy between inventory records and the actual amount of product available presents a problem in retail operations (DeHoratius, Mersereau, Schrage 2006.; Heese 2007). Hence, accurate inventory records are a desired outcome of implementation of RFID technology.

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Insert Figure 1 about here
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2. Literature review and hypotheses

Porter (1985), Baptista and Swann (1998), Hunt and Duhan (2002) and Bentgsson and Sövell (2004) concluded independently that competitive advantages gained by supply chains are influenced by the seeking of efficiency and effectiveness. As such, the purpose of a supply chain in relation to activities is to provide efficiency and effectiveness to the organizations that are members. Further, in order to provide efficiency and/or effectiveness through supply chain activities, it is necessary for an evolution to occur within those supply chains. Supply chain researchers tend to think in terms of either efficiency or effectiveness but not both. However, according to most research in supply chain, the supply chain must first be effective and then move towards becoming more efficient. Thinking probably needs to evolve more towards achieving a balance of efficiency and effectiveness.

Past research has possibly over emphasized efficiency and may in fact confuse efficiency and effectiveness (Walters and Rainbird 2004). As a result, the focus from a strategic perspective has been on the individual organization’s ability to reduce time and costs. Both efficiency and effectiveness are necessary characteristics in regard to supply chain dynamics. Baptista and Swann’s (1998) research indicates that efficiency-seeking and effectiveness-seeking may in fact be repetitive and therefore cyclical. Grant’s (1993) work supports the idea of cyclical nature of the supply chain. He purports that systems of infrastructure are the catalyst for the evolution of supply chains because when kept up and upgraded they revitalize and give new life to supply chains.

This study proposes conceptually that effectiveness and efficiency activities are repetitive, interconnected and cyclical in regard to supply chain dynamics as shown in Figure 1. According to Herrera and Lora (2005), ongoing investment into maintaining and improving
infrastructure such as RFID is critical for the continued viability of supply chain. Accordingly, the basis for any supply chain has to begin with an infrastructure capable of supporting member organizations.

As the supply chain develops, initial focus of the members is on effectiveness via capabilities. As market share and customer base efforts succeed, the supply chain attracts new entrants. Further market success invites competition. These conditions force supply chain members to move to the next stage of the cycle—that being efficiency-seeking activities. As supply chain members solidify customer base and market share their needs outpace existing infrastructure. Then as the supply chain continues to strengthen, improvements in infrastructure are forced by the demands and needs of the channel members. In conjunction with supply chain members achieving results from the focus on efficiency-seeking abilities, they gain additional capabilities and move to the next stage of the supply chain dynamic cycle, effectiveness-seeking. The focus shifts to outcomes and benefits as the result of the evolution or investment in infrastructure systems. Finally, as the supply chain members incorporate the potential benefits and outcomes in this stage, the focus once again shifts to efficiency-seeking and the cycle repeats itself as long as the supply chain members continue to invest dollars in the infrastructure. By not investing in infrastructure the result will be contraction or disintegration of supply chain. This is reflected in the model (Figure 2) proposed in this study.

Insert Figure 2 about here

2.1 Efficiency

Drucker (1955) defined efficiency as doing things right. An attribute of efficiency as described by Porter (1998b) and Drucker (2001) is the shortening of some aspect of the supply
chain. Hanvey, Rexe, and Scott (2003) found that efficiency should be concerned with activities that promote abilities as well as low cost inputs and outputs, such as innovative or resource-seeking activities. Hofer and Schendel (1978) define efficiency as the ratio of actual inputs of the system to its actual outputs. A secondary confirmation of Hofer and Schendel’s findings is identified in a study by Walters and Rainbird (2004) that concludes focus or concentration should be on immediate resources and capacity constraints.

Hofer and Schendel’s (1978) definition of efficiency can be extrapolated from that of the single organization to that of supply chains because supply chain members are engaged in activities that can be mutually beneficial and contribute to competitive advantage. Smart and Harrison (2002) and Mehta (2002) have found that efficiency should also encompass adequate customer satisfaction through supply chain network activities. This customer satisfaction could be gained, for example, through reducing costs and ultimately prices to the customer (Hunt and Duhan 2002; Walters and Rainbird, 2004).

The organizational decision to become a member of a specific supply chain is the result of seeking a characteristic(s) offered by the activity drivers that promote efficiencies (Baptista and Swann 1998). Hunt and Duhan (2002) state from a neoclassic economics perspective, competition is exclusively efficiency-seeking. These authors describe efficiency-seeking as maximizing profits while combining homogenous resources under the conditions of perfect information. Eden (2002) added another effect when she indicated that supply chains already established will have the primary response of becoming efficiency-seeking. Walters and Rainbird (2004) find that most research is focused on efficiency but that effectiveness is probably more important.
2.2 Effectiveness

Drucker (1955) defined effectiveness as *doing the right things*; further concluding that while both (efficiency and effectiveness) are important *doing the right things was far more important than doing things right*. Walters and Rainbird (2004) found that supply chains that are focused on effectiveness are concerned with having access to needed resources. Barnard (1968) and Hofer and Schendel (1978) found that effectiveness in and of itself should be concerned with activities that promote effectiveness, such as market access-seeking and strategic asset-seeking. Hofer and Schendel (1978) and Barnard (1968) define effectiveness as the degree to which the actual outputs of the system correspond to desired outputs.

According to Hunt and Duhan (2002) the neoclassical economist views effectiveness-seeking results as product differentiation. In addition, these authors describe effectiveness-seeking as delivering more value. Effectiveness characterizes supply chains that desire capabilities, outcomes and benefits (Eden, 2002).

For the purpose of this study, the following definitions will be utilized:

1) Efficiency will herein be defined as *characterizing activities that focus on the timely production of goods or services at lower costs*. Activities that are characterized by efficiency-seeking include:
   - resource-seeking
   - innovative activity

2) Effectiveness will herein be defined as *characterizing activities that have the intended or expected potential to enhance outcomes and benefits*. Activities that are characterized by effectiveness-seeking include:
   - market access-seeking
• strategic asset-seeking

2.3 Hypotheses

Angeles’ (2007) work proposes that expected utility theory is one explanation for some equating RFID with increased efficiency. Examination of the Green et al. (2008) and Vijayaraman and Osyk (2006) studies provides evidence that firms have expectations that utilization of RFID can improve organizational and supply chain efficiency. This study seeks to determine whether this expectation is realized by examining hypothesis 1:

H1: RFID technology utilization positively impacts manufacturing efficiency.

Jarillo (1988) proposes that supply chain effectiveness is primary and supply chain efficiency is a later evolutionary step. Both efficiency-seeking and effectiveness-seeking activities comprise the cyclical regeneration of the supply chain (Mason-Jones et al. 2000; Hofer and Schendel 1978). Vijayaraman and Osyk’s (2006) study provides evidence that firms have expectations that utilization of RFID can improve organizational and supply chain effectiveness as well as efficiency. Herrera and Lora (2005) suggest that investment in infrastructure such as RFID is essential for the continued viability of the supply chain. Infrastructure investment is proposed as being one way to provide outcomes and benefits of a type which Eden (2002) characterizes as the pursuit of effectiveness. This study seeks to determine whether investment in a specific infrastructure, RFID, increases supply chain effectiveness by examining Hypothesis 2:

H2: RFID technology utilization positively impacts manufacturing effectiveness.

performance, to reduced manufacturing costs. Hofer and Schendel’s (1978) work link supply chain activities to increased competitive advantage, another measure of organizational performance. This study seeks to determine whether increased supply chain efficiency, and thus manufacturing efficiency, impacts organizational performance by examining Hypothesis 3:

\[ H3: \text{Manufacturing efficiency positively impacts organizational performance.} \]

Improvements in manufacturing efficiency can be obtained through improvements in manufacturing infrastructure. Infrastructure improvements such as RFID increase the availability of real-time manufacturing information which can increase manufacturing efficiency. According to Herrera and Lora (2005) efficiency-seeking investment in manufacturing infrastructure such as RFID is critical to the viability of the supply chain. This relationship between manufacturing efficiency and supply chain performance is the subject of Hypothesis 4:

\[ H4: \text{Manufacturing efficiency positively impacts supply chain performance.} \]

Manufacturing effectiveness derives from effectiveness-seeking activities such as market access-seeking and strategic asset-seeking (Barnard 1968; Hofer and Schendel 1978). The relationship between these effectiveness-seeking activities and supply chain performance is the subject of Hypothesis 5:

\[ H5: \text{Manufacturing effectiveness positively impacts supply chain performance.} \]

Organizational performance is often characterized in terms of effectiveness outcomes such as capabilities, value, and benefits (Eden, 2002; Hunt and Duhan, 2002). Manufacturing effectiveness can be a primary source of increasing these outcomes. This study seeks to determine whether manufacturing effectiveness increases organizational performance by examining Hypothesis 6:

\[ H6: \text{Manufacturing effectiveness positively impacts organizational performance.} \]
Managers are charged with and held accountable for improving the performance of the organizational entity for which they are directly responsible. Within a supply chain context, however, organizational managers must adopt an external focus and must consider the impact of organizational strategies on supply chain partners. Attempts to directly optimize organizational performance may prove to have a detrimental impact on overall supply chain performance, thus damaging the competitive advantage of the chain (Chopra and Meindl 2004; Meredith and Shafer 2002). Chopra and Meindl (2004) argue that supply chain performance is optimized only when an ‘inter-organizational, inter-functional’ strategic approach is adopted by all partners operating within the supply chain. Optimization at the supply chain level maximizes the supply chain surplus available for sharing by all supply chain partners. Strategies that strengthen the competitive position of the supply chain serve to directly enhance supply chain performance which, in time, will positively impact performance at the organizational level for each supply chain partner. Although no empirically tested measure of overall supply chain performance was found, Green et al.’s (2008) survey of 129 manufacturers found that supply chain productivity, a construct similar to supply chain performance, positively impacted organizational performance. Based upon the theoretical justification and empirical evidence, hypothesis seven is stated as follows:

\[ H7: \text{Supply chain performance positively impacts organizational performance.} \]

3. **Methodology**

3.1 **Data collection process**
Data were collected via an on-line data service during the summer of 2008. Two hundred and twenty-three individuals working for manufacturing firms in the U.S. accessed the survey website, and 155 completed the survey, for a response rate of 69.5%. Respondents were asked to select a manufacturing category for their organizations. One hundred and eleven (72%) selected one of 18 different manufacturing categories. The remaining 43 (28%) respondents selected the more general category “other manufacturing.” Respondents average 7.8 years in their current positions and work for firms averaging 6,163 employees and $1.5 billion in annual revenues.

3.2 Measurement scales

The RFID performance model incorporates five constructs: RFID-utilization, manufacturing effectiveness outcomes, manufacturing efficiency outcomes, supply chain performance, and organizational performance. Measurement scales for RFID-utilization, supply chain performance, and organization performance have been previously developed and assessed for validity and reliability (Green et al. 2008; Green, Whitten and Inman 2009; Green and Inman 2005). The manufacturing effectiveness and efficiency outcomes scales are newly developed based on a thorough review of the related literature (Fynes, de Burca, and Voss 2005; Reyes et al. 2007; Cohen and Roussel 2005) and reviewed by a panel of experts in the RFID technology field. The outcomes scales incorporate items reflecting both effectiveness-related and efficiency-related outcomes of RFID implementation. All study scales are presented in Table 1.

Insert Table 1 about here

Non-response bias was assessed using a common approach described by Lambert and Harrington (1990) in which the responses of early and late respondents are compared. One hundred and twenty of the study respondents were categorized as early respondents and 35 were
categorized as late respondents based on whether they responded to the initial or follow-up request to participate. A comparison of the means for the study variables (RFID-utilization, manufacturing effectiveness outcomes, manufacturing efficiency outcomes, supply chain performance, and organizational performance) for the two groups was conducted using one-way ANOVA. The comparisons resulted in statistically non-significant differences. Because non-respondents have been found to descriptively resemble late respondents (Armstrong and Overton 1977), this finding of general equality between early and late respondents supports the conclusion that non-response bias is not a major concern.

Common method bias may lead to inflated estimates of the relationships between independent and dependent variables, when data for the variables are collected from single respondents (Podsakoff and Organ 1986). Harman's one-factor test was used post hoc to examine the potential bias. Substantial common method bias is indicated when either a single factor or one 'general' factor explains a majority of the total variance (Podsakoff and Organ 1986). Results of the factor analysis revealed four factors, which combined to account for 84% of the total variance. The first factor accounted for only 30% of the total variance. Common method bias is, therefore, not a significant problem in this data collection.

4. Results

4.1 Measurement scale assessment

Confirmatory factor analysis was used to assess scale unidimensionality. This was accomplished by creating a separate single-factor measurement model for each of the proposed factors. Examination of overall model fit for each of these models is equivalent to examination of unidimensionality so any number of goodness of fit statistics can be used to test for unidimensionality. Some of the more commonly suggested measures and associated guidelines
are goodness-of-fit index (GFI) values greater than 0.90 (Ahire, Golhar, and Waller 1996), non-normed-fit index (NNFI) and comparative-fit index (CFI) values greater than 0.90 (Garver and Mentzer 1999), and root mean square error of approximation (RMSEA) below 0.08 (Garver and Mentzer 1999). Koufteros (1999) recommends using relative chi-square, non-normed fit index (NNFI), and comparative fit index (CFI) values to assess fit, when the sample size is relatively small, with relative chi-square values of less than 2.00 and NNFI and CFI values greater than .90 indicate reasonable fit. Kline (1998) recommends relative chi-square values of less than the 3.00. Marsch and Hocevar (1985) recommend a less stringent cut-off of 5.00, however.

Confirmatory factor analysis for the RFID utilization scale returned the following values:

relative chi-square = 2.216, GFI = .921, NNFI = .990, CFI = .992 and RMSEA = .089. Values for efficiency outcomes are as follows: relative chi-square = 3.692, GFI = .986, NNFI = .971, CFI = .986 and RMSEA = .132. For effectiveness outcomes, the values are: relative chi-square = 1.486, GFI = .972, NNFI = .996, CFI = .997 and RMSEA = .056. For supply chain performance, the values are: relative chi-square = 3.496, GFI = .957, NNFI = .979, CFI = .990 and RMSEA = .127. For organizational performance, the values are: relative chi-square = 2.480, GFI = .984, NNFI = .988, CFI = .996 and RMSEA = .098. This evidence supports a claim that all study measurement scales are unidimensional.

Garver and Mentzer (1999) recommend computing Cronbach's coefficient alpha to assess scale reliability, with alpha values greater than or equal to 0.70 indicating sufficient reliability. Alpha scores for all of the measurement scales exceed the .70 level. Alpha values for RFID utilization, efficiency outcomes, effectiveness outcomes, supply chain performance, organizational performance measurement scales are .988, .947, .963, .967, and .970, respectively. The study scales are sufficiently reliable.
Ahire et al. (1996) recommend assessing convergent validity using the normed-fit index (NFI) coefficient with values greater than 0.90 indicating strong validity. Garver and Mentzer (1999) recommend reviewing the magnitude of the parameter estimates for the individual measurement items to assess convergent validity. A strong condition of validity is indicated when the estimates are statistically significant and greater than or equal to .70. NFI values for each of the study scales (.986, .981, .992, .985, .994) exceed the .90 threshold, and parameter estimates for each of the individual items exceed the .70 threshold, with values of .86 or greater for all items in all scales. The study scales exhibit sufficient convergent validity.

Discriminant validity was assessed using a chi-square difference test for each pair of scales under consideration, with a statistically significant difference in chi-squares indicating validity (Garver and Mentzer 1999; Ahire et al. 1996; Gerbing and Anderson 1988). All possible pairs of the study scales were subjected to chi-square difference tests with each pairing producing a statistically significant difference indicating sufficient discriminant validity.

Ahire et al. (1996) and Garver and Mentzer (1999) recommend assessing predictive validity by testing whether the scales of interest correlate with other measures as expected. A review of the correlation matrix (see Table 2) for study summary variables indicates that all variables are positively and significantly correlated, as expected, indicating sufficient predictive validity.

Koufteros (1999) recommends that the individual scales be incorporated together in a measurement model and that this model be subjected to an additional confirmatory factor analysis. Results of the analysis indicate that the measurement model fits the data well with a relative chi-square of 1.068, a RMSEA of .021, a GFI of .851, an NNFI of .999, and a CFI of .999. The individual measurement scales are considered sufficiently unidimensional, reliable,
and valid and the fit of the measurement model is considered sufficient to support further assessment of the structural model.

4.2 Structural equation modeling results

Summary values for the study variables were computed by averaging across the items in the scales. Descriptive statistics and the correlation matrix for the summary variables are presented in Table 2. All correlation coefficients are positive and significant at the .01 level.

__________________________
Insert Table 2 about here
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Figure 3 illustrates the model with the structural equation modeling results. The relative chi-square (chi-square/degrees of freedom) value of 1.324 is less than the 3.00 maximum recommended by Kline (1998). The root mean square error of approximation (.046) is less than the recommended maximum of .08 (Schumacker and Lomax 1996). While NNFI (.991) is above the recommended .90 level (Byrne 1998), the GFI (.820) is not. GFI is more heavily impacted by a relatively small sample size, and, as Byrne (1998) points out, the comparative-fit index (CFI) is more appropriate when the sample size is small. The CFI (.994) exceeds the recommended .90 level (Byrne 1998).

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Insert Figure 3 about here
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Five of the seven study hypotheses are supported by the standardized estimates and associated t-values. The relationship between RFID utilization and efficiency outcomes (hypothesis 1) is significant at the .01 level with an estimate of .64 and t-value of 7.76. The estimate of .51 for the relationship between RFID utilization and effectiveness outcomes (hypothesis 2) is significant at the .01 level with a t-value of 6.14. The relationship between
efficiency outcomes and organizational performance (hypothesis 3) is significant at the .01 level with an estimate of .62 and t-value of 9.18. The relationship between efficiency outcomes and supply chain performance (hypothesis 4) is non-significant with a standardized estimate of -0.04 and an associated t-value of -0.69. The relationship between effectiveness outcomes and supply chain performance (hypotheses 5) is significant at the .01 level with a standardized estimate of .82 and t-value of 10.17. The relationship between effectiveness outcomes and organizational performance (hypotheses 6) is non-significant with a standardized estimate of -.0 and a t-value of -0.98. The relationship between supply chain performance and organizational performance (hypotheses 7) is significant at the .01 level with a standardized estimate of .57 and associated t-value of 5.89.

Hair et al. (1998) recommend a competing models approach to structural equation modeling when alternative formulations are suggested by the underlying theory. An alternate model is proposed excluding the links from efficiency outcomes to supply chain performance and effectiveness outcomes to organizational performance and including a link from effectiveness outcomes to efficiency outcomes. This alternative model and associated structural equation modeling results are illustrated in Figure 4.

Insert Figure 4 about here.

The alternate model fits the data slightly better with a relative chi-square of 1.098, RMSEA of .025, GFI of .846, NNFI of .999, and CFI of .999. The added link from effectiveness outcomes to efficiency outcomes is significant at the .01 level with a standardized coefficient of .76 and an associated t-value of 10.31. It should be noted that the results for the alternative model show effectiveness outcomes as partially mediating the relationship between
RFID utilization and efficiency outcomes. This partial mediation is illustrated in the relative
decline in the size of the standardized coefficient for the RFID utilization \( \rightarrow \) efficiency outcomes
from .64 in the theorized model (Figure 3) to .25 in the alternate model (Figure 4).

5. **Conclusions**

Ultimately manufacturing managers are held accountable for the performance of their
organizations. The question in this era of supply chain management is “How best to improve
organizational performance?” The results indicate that manufacturers implementing RFID
technology can expect improvements in both manufacturing efficiency and manufacturing
effectiveness.

The improvements in efficiency lead directly to improved organizational performance.
This utilization of RFID technology impacting manufacturing efficiency follows the studies of
Green et al. (2008) and Vijayaraman and Osyk (2006) and provides evidence that firms’
e xpectations of RFID utilization can improve organizational efficiency.

The improvements in effectiveness, however, do not directly impact the performance of
the organization. The impact is indirect through supply chain performance. This study
determined that investment in a specific infrastructure, like RFID, leads to increased supply
chain effectiveness.

While investment in infrastructure such as RFID is essential for the continued viability of
the supply chain (Herrera and Lora 2005), the infrastructure investment is one way to provide
outcomes and benefits in pursuit of improved supply chain performance. Within a supply chain
context organizational managers must adopt an external (supply chain) focus and must consider
the impact of organizational strategies on supply chain partners.
Manufacturing managers must "do things right" as well as "do the right things" if they are to improve the performance of their organizations. The organization can not be separated from the supply chain and manufacturing managers must strive to minimize costs through efficiency while maximizing satisfaction of the ultimate customer of the supply chain through effectiveness. If manufacturing managers view RFID technology as only leading to improved efficiency, they miss the possibly more important capability of the technology to better satisfy ultimate customers. RFID technology promises both operational and marketing opportunities for the firm. Effectiveness-seeking activities such as market access-seeking and strategic asset-seeking leads to favorable supply chain performance. Managers missing the marketing implications of the technology are likely to undervalue the benefits of technology implementation.

While we believe that the objectives of the study have been accomplished, it is important to note the limitations of the study. First, we focus only on manufacturers. RFID technology is a supply chain technology that impacts all supply chain partners. Future research should focus on the impact of the technology on other supply chain partners especially supply chain service providers such as third and fourth party logistics providers. Second, the study focused only on manufacturing in the United States. Supply chains are global in nature and a broadening of the focus of this study to include international supply chain partners is necessary. Third, the data for this study was collected during the growth stage of the RFID technology life cycle. As the technology is more widely adopted, it will be important to track the impact of the technology throughout the technology's life cycle.

Generally, manufacturing managers can expect improved efficiency and improved effectiveness from investment in RFID technology. Managers should consider both the
operational and marketing-related benefits of the technology as they consider the costs and benefits of such an investment. Manufacturers that are being forced to adopt RFID technology under pressure from customers can take some solace from the results of this study. On the face, it appears that adoption of the technology increases costs with no concomitant increases in benefits. This short sightedness may result from the traditional “efficiency” mindset. Adoption of the technology may in fact lead to more highly satisfied immediate and ultimate customers leading to increased revenues from additional sales.
References


Table 1 – Measurement scales

**RFID utilization (alpha = .988)**

Please indicate the extent to which agree or disagree with each statement (1 = strongly disagree, 7 = strongly agree).

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<table>
<thead>
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<tbody>
<tr>
<td>1.</td>
<td>We currently use RFID technology to manage inventory flows through our manufacturing processes.</td>
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<tr>
<td>2.</td>
<td>Our suppliers are required to provide products to us that facilitate RFID tracking.</td>
</tr>
<tr>
<td>3.</td>
<td>Our customers require us to provide products to them that facilitate RFID tracking.</td>
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<tr>
<td>4.</td>
<td>We use RFID technology to manage raw material inventory levels.</td>
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<tr>
<td>5.</td>
<td>We use RFID technology to manage WIP inventory levels.</td>
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<tr>
<td>6.</td>
<td>We use RFID technology to manage FG inventory levels.</td>
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<tr>
<td>7.</td>
<td>Our current RFID technology facilitates tracking at the item level.</td>
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<tr>
<td>8.</td>
<td>Our current RFID technology facilitates tracking at the bulk (i.e. pallet) level.</td>
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<tr>
<td>9.</td>
<td>We plan to expand the use of RFID technology over the next several years to manage inventory flows through our manufacturing processes.</td>
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**Efficiency outcomes (alpha = .947)**

Please rate your organization’s performance over the last three years in each of the following areas as compared to the industry average (1 = well below industry average, 7 = well above industry average).

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<tbody>
<tr>
<td>1.</td>
<td>Inventory levels.</td>
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<td>2.</td>
<td>Total supply chain cost.</td>
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<td>3.</td>
<td>Warranty/returns processing costs.</td>
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<td>4.</td>
<td>Cash-to-cycle time.</td>
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<td>5.</td>
<td>Inventory days of supply.</td>
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**Effectiveness outcomes (alpha = .963)**

Please rate your organization’s performance over the last three years in each of the following areas as compared to the industry average (1 = well below industry average, 7 = well above industry average).

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<td>1.</td>
<td>Speed of delivery relative to competitors.</td>
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<tr>
<td>2.</td>
<td>Accuracy and availability of information.</td>
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<td>3.</td>
<td>Level of customer service.</td>
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<td>5.</td>
<td>Fill rate.</td>
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<td>6.</td>
<td>Order fulfillment.</td>
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**Supply chain performance (alpha = .967)**

Please indicate the extent to which you agree or disagree with each statement as the statement relates to your organization’s primary supply chain.

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<tr>
<td>1.</td>
<td>This organization’s primary supply chain has the ability to eliminate late, damaged and incomplete orders to final customers.</td>
</tr>
<tr>
<td>2.</td>
<td>This organization’s primary supply chain has the ability to quickly respond to and solve problems of the final customers.</td>
</tr>
<tr>
<td>3.</td>
<td>This organization’s primary supply chain has the ability to deliver products precisely on-time to final customers.</td>
</tr>
<tr>
<td>4.</td>
<td>This organization’s primary supply chain has the ability to deliver precise quantities to final customers.</td>
</tr>
<tr>
<td>5.</td>
<td>This organization’s primary supply chain has the ability to deliver shipments of variable size on a frequent basis to final customers.</td>
</tr>
</tbody>
</table>
**Organizational performance (alpha = .970)**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Average return on investment.</td>
</tr>
<tr>
<td>2.</td>
<td>Average profit.</td>
</tr>
<tr>
<td>3.</td>
<td>Profit growth.</td>
</tr>
<tr>
<td>4.</td>
<td>Average return on sales.</td>
</tr>
</tbody>
</table>

*Please rate your organization's performance over the last three years in each of the following areas as compared to the industry average (1 = well below industry average, 7 = well above industry average).*
Table 2 Descriptive Statistics and Correlation Matrix

Panel A – Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFID Utilization (UTIL)</td>
<td>3.0158</td>
<td>1.90535</td>
</tr>
<tr>
<td>Effectiveness Outcomes (EFFEC)</td>
<td>4.3688</td>
<td>1.66731</td>
</tr>
<tr>
<td>Efficiency Outcomes (EFFIC)</td>
<td>4.0452</td>
<td>1.59032</td>
</tr>
<tr>
<td>Supply Chain Performance (SCP)</td>
<td>4.5897</td>
<td>1.66722</td>
</tr>
<tr>
<td>Organizational Performance (OP)</td>
<td>4.2403</td>
<td>1.62541</td>
</tr>
</tbody>
</table>

Panel B - Correlation Matrix

<table>
<thead>
<tr>
<th>Variable</th>
<th>UTIL</th>
<th>EFFEC</th>
<th>EFFIC</th>
<th>SCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFID Utilization (UTIL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effectiveness Outcomes (EFFEC)</td>
<td>.413</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficiency Outcomes (EFFIC)</td>
<td>.532</td>
<td>.835</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Chain Performance (SCP)</td>
<td>.391</td>
<td>.746</td>
<td>.609</td>
<td></td>
</tr>
<tr>
<td>Organizational Performance (OP)</td>
<td>.524</td>
<td>.740</td>
<td>.767</td>
<td>.750</td>
</tr>
</tbody>
</table>

Note: All coefficients significant at the 0.01 level (2-tailed).
Figure 1
RFID with Efficiency and Effectiveness
Figure 2
RFID Utilization and Outcomes Performance Model
with Hypotheses
Figure 3
RFID Utilization and Outcomes Performance Model
with standardized coefficients and ($t$-values)
Relative Chi-Square = 1.324; RMSEA = .046; GFI = .820;
NNFI = 0.991; CFI = .992
Figure 4

Alternate RFID Utilization and Outcomes Performance Model
with standardized coefficients and (t-values)

Relative Chi-Square = 1.098; RMSEA = .025; GFI = .856;
NNFI = .999; CFI = .999