

RADIO FREQUENCY IDENTIFICATION TECHNOLOGY UTILIZATION AND ORGANIZATIONAL AGILITY

PAMELA J. ZELBST
Sam Houston State University
Huntsville, TX 77341-2056

VICTOR E. SOWER
Sam Houston State University
Huntsville, TX 77341-2056

KENNETH W. GREEN, JR.
Southern Arkansas University
Magnolia, Arkansas 71754

ROGER D. ABSHIRE
Sam Houston State University
Huntsville, TX 77341-2056

ABSTRACT

This study examines the impact of RFID technology utilization on organizational agility in manufacturing firms. Data from a sample of 328 manufacturers were collected and the model was assessed following a structural equation methodology. Findings indicate that adoption of RFID technology utilization directly and positively impacts organizational agility which in turn directly and positively impacts both operational and logistics performance. Additionally, operational performance directly and positively impacts logistics performance. Data were collected during the growth stage of RFID technology adoption and were only collected from firms in the manufacturing sector. Respondents held operations-level positions in manufacturing organizations. Results should be interpreted with these limitations in mind. The implementation of RFID technology can result in improved organizational agility resulting in improved performance. Practitioners considering adoption of RFID technology should weigh potential benefits from increased agility and performance against the costs of technology adoption.

KEYWORDS: RFID technology, organizational agility, operational performance, logistics performance.

1. INTRODUCTION

Radio Frequency Identification (RFID) has been around for a number of years and is touted as one of the most important innovations in several decades [49]. The initial focus of RFID was on security as is evident in its use in the friend or foe program in Britain during WWII [21]. In recent years the technology has been used in many areas including inventory management, process control, asset tracking, and monitoring [29; 17; 55]. RFID utilization enhances the timeliness of production information [5], creates tracking ability allowing for traceability of inventories [14; 29] and increases service level capabilities [24] resulting in organizational growth and profitability [27; 7]. RFID technology also has implications for improving performance at the supply chain level [45].

RFID, while more expensive, has significant advantages over bar codes—and the cost differential is rapidly narrowing. RFID tags do not require line-of-sight in order to be read and depending upon the type of tag can be read at greater distances. RFID tags can also be read so much faster than bar codes that it appears that all tags in a center are read simultaneously rather than sequentially

as with bar codes. RFID has read/write capability that bar codes lack. RFID tags are more durable than bar codes and may be implanted within products assuring long-term traceability. These advantages facilitate an organization's ability to provide timely information required for agile performance.

Organizations with established enterprise resource planning systems have the ability to synchronously share real-time information with supply chain partners [15]. We argue that RFID technology serves to enhance the ability of manufacturing organizations to share information with suppliers and customers better enabling those organizations to rapidly respond to changes in customer demand. RFID technology allows the real-time capture and sharing of inventory-related information across the supply chain.

It is our purpose to investigate the impact of RFID technology utilization on organizational agility and the impact of both RFID technology utilization and organizational agility on operational performance and logistics performance. We build on recent empirical findings that RFID technology utilization and organizational agility positively impact performance [14; 22; 56]. These studies [14; 22; 56] do not combine RFID technology utilization and organizational agility within the same model, however, as does the structural model proposed here. Specifically, we propose that adoption of RFID technology utilization positively affects an organization's agility leading to improved operational and logistics performance by providing higher quality and more timely information to the organization as well as providing the technological capability to capture and utilize that information in ways that are much more difficult or impossible with other technologies. While measurement scales from previous studies [14; 15; 22; 56] are used, the structural model tested is new with the incorporation of both RFID technology utilization and organizational agility constructs. Data from a sample of U.S. manufacturing organizations is used to assess a theorized structural model following a structural equation modeling methodology.

The following section presents a theoretical model with support from the existing literature and develops the study hypotheses accompanied by theoretical and empirical support. The methodology section follows including discussions of the data collection process, construct measurement, and statistical analyses used to assess the measurement scales and the structural model. The results section presents the results and accompanying interpretations for the measurement model assessment, the

structural model assessment, and the individual study hypothesis tests. Finally, a section with discussion and conclusions is presented.

2. LITERATURE REVIEW AND HYPOTHESES

2.1 The Model and Hypotheses

We theorize a structural model incorporating RFID technology utilization as antecedent to organizational agility, RFID technology utilization and organizational agility as antecedents to operational performance and logistics performance, as well as organizational performance as antecedent to logistics performance. Generally, we propose that RFID technology utilization positively impacts organizational agility which, in turn, positively impacts organizational performance. RFID technology provides additional inventory-related information on a real-time basis that can be shared synchronously with supply chain partners. This additional information enhances the ability of manufacturing organizations to respond to changes in customer demand through improved organizational agility. This enhanced agility leads to improved efficiency (operational performance) and customer satisfaction (logistics performance). This model is presented in Figure 1.

2.2 Technology diffusion and RFID Utilization

Previous research found evidence that diffusion of technology can have an advantageous effect on economic growth in and across countries [23]. Technology diffusion in manufacturing impacts productivity in a manufacturing environment [11]. Diffusion of information technology allows companies to be proactive, reactive, and create change [43]. These elements are all considered to be agile activities [8]. RFID is a technology that provides a means of collecting timely information, and the diffusion of RFID technology can provide ways for companies to be both proactive and reactive and to create change.

RFID systems are rapidly replacing Universal Product Codes (barcodes) [50]. To date, cost has been the major barrier to the utilization of RFID [41]. Costs are, however, decreasing which should make RFID technology more accessible. RFID utilization

has been found to enable improved manufacturing performance [18]. More organizations are realizing the benefits of employing RFID to track inventory within the organization. Manufacturing organizations can benefit from greater inventory visibility via the real-time information provided by RFID technology to manage the flow of inventory [6]. RFID technology has been found to speed up the flow of information allowing for greater visibility of inventories as they flow through the manufacturing processes [25]. RFID can be used to track all types of inventory, such as raw materials, work-in-progress (WIP), and finished goods inventories, through the manufacturing process [50]. The level of tagging (item, case, or pallet) can be crucial for an organization [57]. Currently most items are tagged primarily at the case and pallet level, as the cost of the technology goes down, organizations will begin to tag at the item level.

The adoption of RFID technology has implications for performance at the supply chain level, as well as at the organizational level. Based on a recent review of related literature, RFID technologies may improve performance at the supply chain level by reducing inventory losses, increasing the efficiency and agility of processes, and improving information accuracy [45]. Additionally, based on simulation results, RFID technology adoption is most beneficial within a supply chain context when the level of collaboration among the supply chain partners is relatively intensive [46].

2.3 Hypotheses

Agile organizations are characterized as being proactive, reactive and change creating [8]. Agility requires physical and fiscal quickness to respond to unpredictable events. Agility in a manufacturing context has been described as the ability to “efficiently change operating states in response to uncertain and changing demands” [36]. RFID technology is reported to have the potential to enhance supply chain agility [54].

The integration of information technology was found to result in increased agility for an organization and should ultimately have a positive influence on competitive business performance in areas such as response to changes in customer demand, response to market changes, and the capability to sense, perceive and anticipate market changes [54]. RFID enables organizations to

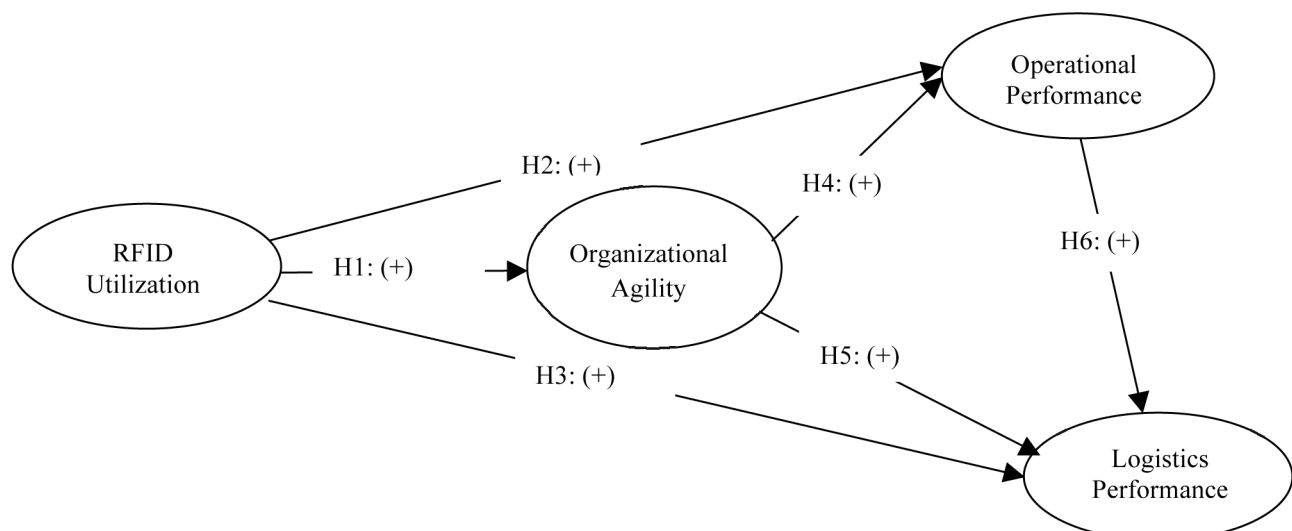


FIGURE 1 — RFID Technology Utilization and Organizational Agility Performance Model with Hypotheses

support proactive management through use of real-time data [37]. Customers' rapidly changing needs emphasize the point that organizations must be able to respond quickly with necessary changes to internal processes and products [19]. Accordingly, technology diffusion theory and prior research suggests that organizations utilizing RFID technology should then be able to efficiently provide current information that allows organizations to become more agile. Based on this theoretical and empirical justification, we hypothesize the following:

H1: RFID technology utilization positively impacts organizational agility.

It can be argued that technology diffusion in manufacturing impacts productivity in a manufacturing environment [11]. Operational performance is defined as, "the performance related to organizations' internal operations, such as productivity, product quality and customer satisfaction." [10] Operational performance is also dependent upon an organization's capabilities and technologies [16]. Several measures of operational performance have been identified as throughput, inventory, and operating expense [33; 20]. Organizations focusing on underlying technologies find an improvement in throughput, inventory expense, and operating expense ultimately resulting in a positive impact on operational performance [20]. RFID is an emerging technology that is increasingly being utilized in manufacturing. Based on this theoretical and empirical justification, we hypothesize the following:

H2: RFID technology utilization positively impacts operational performance.

Evidence that diffusion of technology can have an advantageous effect for organizations has been found [23]. The need for performance measurement has been identified [47]. Logistics performance captures a measure of performance that is external (manufacturer/ supplier) to the organization [15]. Logistics performance reflects an organization's ability to satisfy customers through the on-time delivery of quality products and services [4]. Logistics performance can be measured as a composite of customer satisfaction, responsiveness, delivery dependability [38], delivery speed [52], flexibility [53] and capacity. Organizations utilizing RFID technology can expect to be more responsive to customers logistically [3]. Further, it was found that lead time dropped from 497 days to 24 hours resulting in a dramatic 60% drop in stock level following the implementation of RFID technology [3]. Based on this theoretical and empirical justification, we hypothesize the following:

H3: RFID technology utilization positively impacts logistics performance.

Agility is perceived to be vital to maintaining competitive advantage in a manufacturing environment [47]. The focus of the previous research was on model development for the assessment of agility, but they did stress the need for performance measurements [47]. Technology diffusion in manufacturing has been found to impact productivity, a component of operational performance [11]. In addition, diffusion of information technology has been found to allow companies to be proactive, reactive and create change [43]. Based on technology diffusion theory and prior research, we hypothesize the following:

H4: Organizational agility positively impacts operational performance.

Logistics performance is the ability to respond to customers' ever-changing wants and needs in a timely way [56]. The utilization of technologies such as RFID can lead to agility in organizations [1]. Organizations that are agile have the capability to respond to unexpected changes and increase processing speed [32], thus increasing logistics performance. The integration of information technology is likely to result in more agility for an organization resulting in better response to market changes as well as enhancing the capability to sense, perceive and anticipate market changes [52]. Based on this theoretical and empirical justification, we hypothesize the following:

H5: Organizational agility positively impacts logistics performance.

Previous researchers argue that operational performance is influenced by logistics performance [51]. Other researchers found that operational performance positively impacts logistics performance [56]. They also found that operational performance positively impacts logistics performance but did not test this hypothesis in a context of technology diffusion. Researchers examined overall firm performance in a digitally-enabled supply chain and found that information related technology impacted supply chains, but did not examine whether operational performance impacts logistics performance [42]. Based on this theoretical and empirical justification, we hypothesize the following:

H6: Operational performance positively impacts logistics performance.

3. METHODOLOGY

3.1 Data collection process

In this study, RFID technology utilization and organization agility are described as capabilities employed by manufacturing firms. The data collection process, therefore, focused on building a data set from a representative sample of the population of U.S. manufacturing firms. Data from a sample of 328 individuals working in U.S. manufacturing plants were collected via an on-line data service (MarketTools, Inc.) during the spring of 2009. Approximately 2,000 individuals working for manufacturing plants in the U.S. were invited to participate in the survey. Of the 2,000 individuals invited, 328 accessed the survey website and completed the survey for an effective response rate of 16.4%. While this is a relatively high response rate for recent empirical studies conducted within the manufacturing sector [22], the response rate does raise possible concerns as to the validity and reliability of the study measures and results of the study. To address these concerns, we used measures that have been previously assessed for validity and reliability coupled with a thorough assessment using data from the current sample alleviate concerns related to the measurement scales. The more general concern, that the majority of the potential respondents did not participate, remains, necessitating caution when extrapolating the results of the study to the entire population. However, it should be noted that the sample is relatively diverse representing a cross-section of the U.S. manufacturing

sector which should support reasonable generalization of the study results.

Respondents were categorized as either managers (plant manager, operations manager, purchasing manager, engineering manager), supervisors (directly supervise operations/production/technical workers), or operations/production/technical workers (working directly within the production process to manufacture products). Of the respondents, 7.6% held manager positions, 14% held supervisor positions, and the remaining 78.4% held operations/production/technical worker positions. Measurement scale item means for the three categories were compared using ANOVA with no significant differences (at the .01 level) noted. Respondents average 8.8 years in their current positions and work for firms averaging 783 employees and \$1.5 billion in annual revenues. Respondents were asked to select a manufacturing category for their organizations. Two hundred and twenty-three (68%) selected one of 18 specific SIC categories. The remaining 105 (32%) respondents selected the more general default category "other manufacturing." It should be noted that due to financial constraints it was only possible to contact potential respondents once.

We believe that individuals working within plants are those best suited to respond to the measurement scale items for constructs such as RFID technology utilization, organizational agility, operational performance, and logistics performance. As intended, the study sample represents a relatively diverse group of respondents with knowledge of their organizations' efforts to implement RFID technology, level of agility in terms of responding to changes in customer demand, and levels of operational and logistics performance. While individuals in corporate level positions develop policy and strategy, those individuals working within the manufacturing plants themselves are best suited to provide information related to the actual implementation and effects of implementation of policies and strategies. While collection of data from the operational level of the manufacturing organization was our intent, we note and understand the potential limitation especially where information related to supply chain performance is concerned. As was our intent, the sample exhibits diversity with respondents representing a cross-section of industries and with knowledgeable respondents representing the plant-level of the manufacturing organizations.

3.2 Common method bias

When data for the independent and dependent variables are collected from single informants, common method bias may lead to inflated estimates of the relationships between the variables [40]. To reduce the potential for common method bias, care was taken to 1) develop scale items that are simple and unambiguous, 2) format the survey such that scales representing dependent constructs appeared before those representing independent constructs (operational performance and logistics performance before organizational agility), 3) separating the scales for the focal constructs (RFID technology utilization and organizational agility) with additional scales not related to this study, 4) using various instruction sets and anchor combinations for the study scales, and 5) taking steps to ensure respondent anonymity, as recommended [39].

Although common method variance (CMV) can be of concern in same-source, cross-sectional data, there is no current consensus that it necessarily exists at a biasing level in data [44]. There is evidence that the levels of common method variation in

such studies is negligible and that it does not bias relationships such that it significantly affects research conclusions [9; 48]. One study recommends use of the CFA marker technique to determine if CMV is present in the data [44]. This method requires that a measurement scale for a marker construct be included in the survey. A marker construct is theoretically unrelated to the study constructs. Unfortunately, no such scale was included precluding assessment of common method bias using the CFA marker technique.

We assess the impact of common method variance using two *post hoc* approaches. First, Harman's one-factor test was used *post hoc* to examine the extent of the potential bias [40]. As prescribed by Harman's test, all variables were entered into a principal components factor analysis. Results of the factor analysis (maximum likelihood, varimax rotation) of all scale items (Appendix A) revealed 4 factors with eigenvalues greater than one, which combined to account for 76% of the total variance. While the first factor accounted for 25% of the total variance, it did not account for a majority of the variance. Second, when a marker variable has not been included in the data collection, it is recommended that the smallest correlation among the variables be used as a proxy for common method variation [30]. Following this approach, the smallest correlation is .326 between RFID technology utilization and logistics performance. The second smallest correlation is .401 for RFID technology utilization and operational performance. Substituting these correlations into the formulas the computed z-score is 2.01 [34]. This computed z-score corresponds with significance at the .044 level. Adjusting for common method variance using the smallest correlation (.326), the second smallest correlation (.401) remains significantly different from zero at the .05 level. Based on the results of one-factor test and the proxy tests, problems associated with common method bias are not considered significant [40; 31].

3.3 Construct measurement and statistical analyses

The structural model under investigation incorporates four constructs: RFID technology utilization, organizational agility, operational performance, and logistics performance. The RFID technology utilization scale was originally developed and assessed in a study [14]. The agile manufacturing scale is taken from a previous study [22]. The operational performance scale is taken from previous research [56]. The logistics performance scale is taken from a previous study [15]. All study scales are presented in Appendix A. The measurement scales are assessed individually for unidimensionality, validity, and reliability. The scales are then incorporated into a measurement model and assessed for fit. Summary variables are then computed and descriptive statistics developed. The theorized model is then assessed following a structural equation modeling methodology.

4. RESULTS

4.1 Measurement scale assessment

Quality measurement scales must exhibit content validity, unidimensionality, reliability, discriminant validity, and convergent validity. All scales were taken directly from prior research [14; 22; 56], in which content validity was demonstrated. Results used to assess all scales are found in Table 1.

Unidimensionality was assessed using confirmatory factor analysis on each of the individual study scales [13]. It is

TABLE 1. Scale Assessment Results

Reliability, dimensionality, and convergent validity assessment results

| Scale | Alpha | Relative χ^2 | GFI | RMSEA | NNFI | CFI | NFI |
|-------------------------|-------|-------------------|------|-------|------|------|------|
| RFID Utilization | .981 | 3.796 | .956 | .092 | .990 | .994 | .991 |
| Agile Manufacturing | .955 | 2.140 | .962 | .059 | .993 | .995 | .991 |
| Operational Performance | .882 | 4.838 | .971 | .108 | .969 | .985 | .981 |
| Logistics Performance | .963 | 9.56 | .945 | .162 | .966 | .983 | .981 |

recommended to use relative chi-square, non-normed fit index (NNFI), and comparative fit index (CFI) values to assess fit when the sample size is relatively small [28]. Relative chi-square values of less than 2.00 and NNFI and CFI values greater than .90 indicate reasonable fit [28]. One study [26] recommends relative chi-square values of less than the 3.00, while another study [35] applies a somewhat less stringent cut-off of 5.00.

In order to achieve unidimensionality, it was necessary to remove items 4 and 5 from the RFID technology utilization scale, item 8 from the organizational agility scale, items 2, 3, and 4 from the operational performance scale, and item 2 from the logistics performance scale. NNFI and CFI values from the confirmatory factor analyses for all other scales exceed the recommended value of .90. The relative chi-square values for all scales exceed the most stringent limit of 2.00 recommended by previous research [28]. Only the relative chi-square value for the logistics performance scale exceeds the less strict limit of 5.00 as recommended by previous research [35]. This evidence supports a general claim of sufficient unidimensionality for all study scales.

One study recommends computing Cronbach's coefficient alpha to assess scale reliability, with alpha values greater than or equal to 0.70 indicating sufficient reliability [12]. Alpha scores for all of the measurement scales exceed the .70 level. Alpha values for RFID technology utilization, organizational agility, operational performance, and logistics performance are .981, .981, .882, and .963, respectively. Thus, the study scales are sufficiently reliable.

It is recommend assessing convergent validity using the normed-fit index (NFI) coefficient with values greater than 0.90 indicating strong validity [2]. Another study recommends reviewing the magnitude of the parameter estimates for the individual measurement items to assess convergent validity [12]. Sufficient convergent validity is indicated when the estimates are statistically significant and greater than or equal to .70. NFI values for the RFID technology utilization (.99), organizational agility (.99), operational performance (.98), and logistics performance (.98) scales exceed the .90 threshold. All parameter estimates for each of the individual items in the study scales are significant with values greater than .70. All 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 [12; 2; 13]. All possible pairs of the study scales were subjected to chi-square difference tests with each pairing producing a statistically significant difference.

4.2 Measurement model assessment

Previous research recommends that the individual scales be incorporated together in a measurement model and that this

model be subjected to an additional confirmatory factor analysis and that relative chi-square, non-normed fit index (NNFI), and comparative fit index (CFI) values be used to assess fit when the sample size is relatively small [28]. Results of the analysis are reported in Table 2. Relative chi-square values of less than 2.00 and NNFI and CFI values greater than .90 indicate reasonable fit [28]. Results indicate that the measurement model fits the data relatively well with an NNFI of .98, and a CFI of .98. The relative chi-square of 3.10 is higher than the recommended value of 2.00, but is well below the 5.00 level recommended in a previous study [35]. Individual measurement scales are considered sufficiently reliable and valid and the fit of the measurement model is considered sufficient to support further analysis.

TABLE 2. Measurement Model Results

Chi-square ratio = 3.10; RMSEA = .08; NFI = .97; NNFI = .98; CFI = .98; IFI = .98; GFI = .82

| Construct/Measures | Std. Coefficients | t-values |
|-----------------------------|-------------------|----------|
| RFID Technology Utilization | | |
| RFID1 | .95 | 23.36 |
| RFID2 | .95 | 23.30 |
| RFID3 | .93 | 22.17 |
| RFID6 | .97 | 24.16 |
| RFID7 | .97 | 24.18 |
| RFID8 | .94 | 22.65 |
| RFID9 | .92 | 21.76 |
| Organizational Agility | | |
| OA1 | .82 | 18.20 |
| OA2 | .85 | 18.94 |
| OA3 | .88 | 20.23 |
| OA4 | .92 | 21.93 |
| OA5 | .88 | 20.12 |
| OA6 | .88 | 20.33 |
| OA7 | .83 | 18.47 |
| OA9 | .90 | 20.94 |
| OA10 | .86 | 19.50 |
| Operational Performance | | |
| OP1 | .83 | 18.20 |
| OP5 | .86 | 19.04 |
| OP6 | .85 | 18.87 |
| OP7 | .75 | 15.53 |
| OP8 | .74 | 15.32 |
| Logistics Performance | | |
| LP1 | .91 | 21.45 |
| LP3 | .93 | 22.33 |
| LP4 | .96 | 23.44 |
| LP5 | .93 | 22.38 |
| LP6 | .94 | 22.65 |

4.3 Structural equation modeling results

Summary values for the study variables were computed by averaging the items in the scales. Descriptive statistics and the correlation matrix for the summary variables are presented in Table 3. All correlation coefficients are positive and significant at the .01 level.

Figure 2 illustrates the model with the structural equation modeling results. The relative chi-square (chi-square/degrees of freedom) value of 3.10 is slightly higher than the 3.00 maximum recommended in one study [26] but less than the 5.00 recommended in another study [35]. The NNFI (.98) and CFI (.98) exceed the .90 level recommended in previous research [28].

Five of the six study hypotheses were supported by the standardized estimates and associated *t*-values. The relationship between RFID technology utilization and organizational agility (hypothesis 1) is positive and significant at the .01 level as hypothesized with an estimate of .46 and *t*-value of 8.22. The estimate of .12 for the relationship between RFID technology utilization and operational performance (hypothesis 2) is positive and significant at the .01 level as hypothesized with an associated *t*-value of 2.79. Although hypothesized as positive, the relationship between RFID technology utilization and logistics performance (hypothesis 3) is negative with an estimate of -.07 and *t*-value of -2.02 which is significant at the .05 level. The

standardized estimate of -.07 is not absolutely large indicating that RFID technology utilization has relatively little direct impact on logistics performance. The claim of significance at the .05 level is more likely associated with the relatively large sample size.

The relationship between organizational agility and operational performance (hypothesis 4) is positive and significant at the .01 level as hypothesized with an estimate of .75 and an associated *t*-value of 13.14. The relationship between organizational agility and logistics performance (hypothesis 5) is positive as hypothesized with a standardized estimate of .42 and an associated *t*-value of 7.21. The relationship between operational performance and logistics performance (hypothesis 6) is positive as hypothesized with a standardized estimate of .55 and *t*-value of 8.82.

4.4 Summary of results

The measurement scales are sufficiently valid and reliable and the measurement model fits the data relatively well. Results of the assessment of the structural model support five of the six study hypotheses. Generally, RFID technology utilization positively impacts organizational agility which, in turn, positively impacts both operational performance and logistics performance. In addition, operational performance positively impacts logistics performance. While the results indicate that RFID technology utilization positively impacts operational performance and

TABLE 3. Descriptive Statistics and Correlations

| Summary Variable | Mean | St. Dev. | RFID | OA | OP | LP |
|------------------------------|-------|----------|--------|--------|--------|------|
| RFID Utilization (RFID) | 3.778 | 1.914 | 1.00 | | | |
| Organizational Agility (OA) | 5.282 | 1.291 | .401** | 1.00 | | |
| Operational Performance (OP) | 5.101 | 1.173 | .411** | .743** | 1.00 | |
| Logistics Performance (LP) | 5.662 | 1.212 | .326** | .787** | .770** | 1.00 |

** Correlation is significant at the 0.01 level (2-tailed).

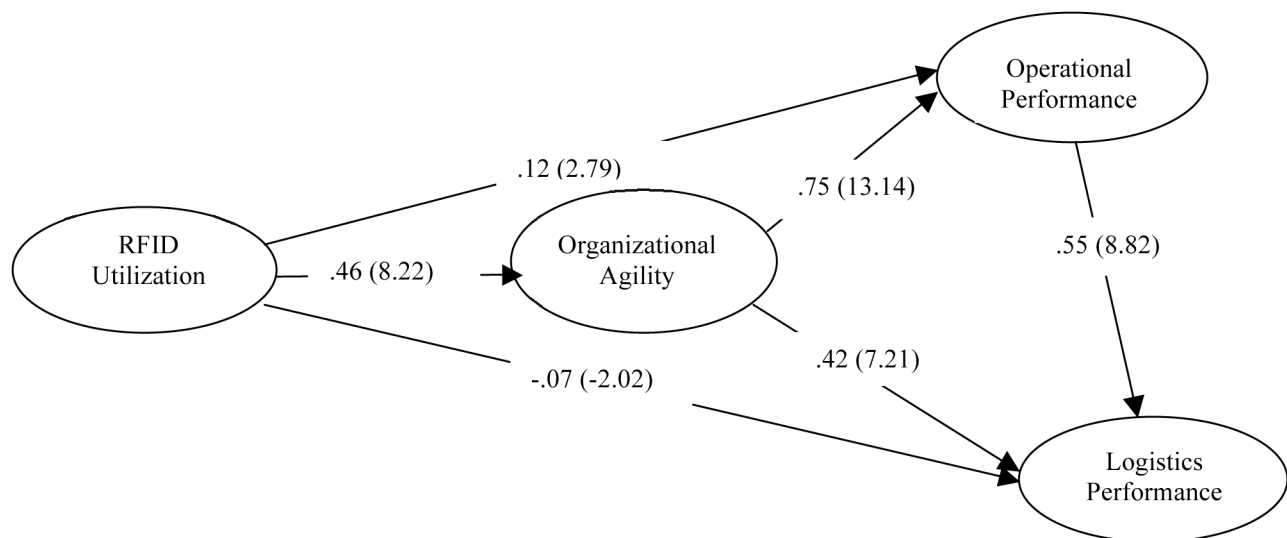


FIGURE 2

RFID Technology Utilization and Organizational Agility Performance Model with standardized estimates and (t-values)

Relative Chi-Square = 3.10; NFI = .97; RMSEA = 0.08; CFI = 0.98; IFI = 0.98; NNFI = 0.98; SRMR = 0.04

negatively impacts logistics performance, the standardized estimates are relatively small (.12 and -.07) compared to the standardized estimate (.46) for the impact of RFID technology utilization on organizational agility. To summarize, the results indicate that RFID technology utilization leads to improved organizational agility driving improvements in both operational and logistics performance.

5. CONCLUSIONS AND DISCUSSION

This study and the associated findings build on previous works [14; 22; 56] that have established empirical relationships between the two focal constructs within this study (RFID technology utilization and organizational agility) and organizational and supply chain performance constructs. The model incorporates constructs previously defined and described and the survey instrument included previously developed and assessed measurement scales [14; 15; 22; 56]. The significant contribution of this study is the coupling of RFID technology utilization and organizational agility within a single structural model and the assessment of the combined impact on performance. The results related to measurement scale validity and reliability replicate the results from previous studies [14; 15; 22; 56] and the separate correlations for the relationships of RFID technology utilization and performance and organizational agility and performance variables replicate the findings from previous studies [14; 15; 22; 56]. What is newly reported here is the positive association between RFID technology utilization and organizational agility. RFID technology utilization enhances an organization's ability to respond to changes in customer demand. In other words, manufacturing organizations that have adopted RFID technology are more agile and manufacturing organizations that are more agile exhibit higher levels of operational and logistics performance.

RFID technology utilization directly impacts an organization's agility and operational performance but does not directly impact logistics performance. The negative relationship between RFID technology utilization and logistics performance is surprising and requires additional discussion. When viewed in isolation, the pairing of RFID technology utilization and logistics performance are positively and significantly correlated (.326, significant at the .01 level). When the relationship is incorporated within the context of the structural model (Figure 2), RFID technology utilization appears to indirectly impact logistics performance through both organizational agility and operational performance. This suggests that the impact of RFID technology utilization on logistics performance is mediated through agility and operational performance with agility having the strongest meditational effect. The technology synchronously provides organizations with real-time information that facilitates efficient and effective response to changes in customer demands and markets that facilitates improved logistics performance. The findings provide support for the general proposition that RFID technology utilization enhances agility and improves performance.

While we believe that we have accomplished the objectives of the study, limitations should be noted. Data were collected during the growth stage of RFID technology adoption and were only collected from firms in the manufacturing sector. While some respondents hold managerial and supervisory positions, the majority hold operations-level positions within manufacturing organizations. Because of financial restrictions, it was not possible to conduct a follow-up wave of data collection making it impossible to assess non-response bias. Results should be interpreted with these limitations in mind.

Future research should follow the progression of technology implementation from growth through to maturity stage. Additional research should investigate the impact of the technology on agility and performance within the services and governmental sectors. Because this is one of the first empirically-based studies investigating the impact of RFID technology implementation on organizational agility, replication of this study with other samples is important to generalization of the findings. The model assessed is limited in that it includes only RFID technology utilization and organizational agility as antecedents to operational and logistics performance. Because RFID technology utilization is integrated within manufacturing, purchasing, and logistics processes that likely incorporate such improvement programs as Just-in-Time, Total Quality Management, and Lean, additional research that incorporates such constructs into the RFID technology utilization and organizational agility model are needed. It should also be noted that it is desirable to incorporate a measure of supply chain performance in an expanded model since RFID technology has implications at both the organizational and supply chain levels.

Manufacturing organizations must strive to be both efficient in terms of minimizing costs associated with the manufacturing process and effective in terms of satisfying customers. RFID technology adoption supports both the cost minimization objective of the operations function and the customer satisfaction objective of the marketing function. The study results provide evidence that RFID technology directly impacts operational performance thereby enhancing the efficiency of the organization and reducing costs associated with the manufacturing of the product. The results also support a claim that RFID technology utilization enhances the firm's ability to respond to changes in customer demands through improved agility with agility leading to improved logistics performance. Lower costs can be used either to increase profit margins or increase sales revenues through reduced prices to customers. Satisfied customers will likely lead to improved market share and sales revenues. More simply put, manufacturing practitioners adopting RFID technology can expect improved organizational agility that enhances both operational and logistics performance. Adopting organizations will, therefore, likely experience improved profitability from a combination of increased revenues and decreased costs. Practitioners considering adoption of RFID technology should weigh these potential benefits against the costs of technology adoption.

APPENDIX A — Measurement Scales

(* indicates items removed to achieve unidimensionality)

RFID utilization

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

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

Organizational Agility

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

1. We have the capabilities necessary to sense, perceive and anticipate market changes.
2. Our production processes are flexible in terms of product models and configurations.
3. We react immediately to incorporate changes into our manufacturing processes and systems.
4. We have the appropriate technology and technological capabilities to quickly respond to changes in customer demand.
5. Our strategic vision emphasizes the need for flexibility and agility to respond to market changes.
6. We have formed co-operative relationships with customers and suppliers.
7. Our managers have the knowledge and skills necessary to manage change.
8. *We have the capabilities to meet and exceed the levels of product quality demanded by our customers.
9. We have the capabilities to deliver products to customers in a timely manner and to quickly respond to changes in delivery requirements.
10. We can quickly get new products to market.

Operational Performance

Please rate your organization's performance in each of the following areas as compared to the industry average. (1=well below industry average; 7=well above industry average)

1. Throughput
2. *Inventory expense
3. *Operating expense
4. *Lead time
5. Product cycle time (throughput time)
6. Due date performance
7. Inventory levels
8. Cash flow

Logistics Performance

Please rate your company's performance in each of the following areas as compared to the performance of your competitors. (1=much worse than competition, 7=much better than competition)

1. Customer satisfaction
2. *Delivery speed
3. Delivery dependability
4. Responsiveness
5. Delivery flexibility
6. Order fill capacity

REFERENCES

- [1] Abrahamsson, P., Hanhineva, A., and Jääliñoja, J. "Improving business agility through technical solutions: a case study on test-driven development in mobile software development." *Business Agility and Information Technology Diffusion*, edited by Baskerville, R. L., Mathiassen, L., Pries-Heie, J., and DeGross, J. I. Springer Science+Business Media, Inc.: New York, NY, 2005.
- [2] Ahire, S. L., Golhar, D. Y., and Waller, M. A. "Development and validation of TQM implementation constructs." *Decision Sciences*, Vol. 27(1), 1996, pp. 23-56.
- [3] Azevedo, S. G. and Ferreira, J. "RFID technology in retailing: an exploratory study on fashion apparels." *The IUP Journal of Managerial Economics*, Vol. 7(1), 2009, pp. 7-22.
- [4] Bowersox, D. J., Closs, D. J., Stank, T. P. and Keller, S. B. "How supply chain competency leads to business success," *Supply Chain Management Review*, Vol. 4(4), 2000, pp. 70-78.
- [5] Brandyberry, A., Rai, A., and White, G. P. "Intermediate performance impacts of advanced manufacturing technology systems: an empirical investigation." *Decision Sciences*, Vol. 30(4), 1999, pp. 993-1020.
- [6] Brintrup, A., Ransinghe, D., and McFarlane, D. "RFID opportunity analysis for leaner manufacturing." *International Journal of Production Research*, Vol. 48(9), 2010, pp. 2745-2764.
- [7] Byrd, T. A. and Davidson, N. W. "Examining possible antecedents of IT impact on the supply chain and its effect on firm performance." *Journal of Operations Management*, No. 41(2), 2003, pp. 243-255.
- [8] Conboy, K., Fitzgerald, B., and Golden, W. "Agility in information systems development: a three-tiered framework." *Business Agility and Information Technology Diffusion*, edited by Baskerville, R. L., Mathiassen, L., Pries-Heie, J., and DeGross, J. I. Springer Science+Business Media, Inc.: New York, NY, 2005.
- [9] Crampton, S. M., and Wagner III, J. A.. "Percept-percept inflation in microorganizational research: an investigation of prevalence and effect." *Journal of Applied Psychology*, Vol. 79(1), pp. 67-76.
- [10] Feng, M., Terziovski, M., and Samson, D. 2008. "Relationship of ISO 9001:2000 quality system certification with operational and business performance: a survey in Australia and New Zealand-based manufacturing and service companies." *Journal of Manufacturing Technology Management*, Vol. 19(1), 1994, pp. 22-37.
- [11] Frantzen, D. "Technological diffusion and productivity convergence: a study for manufacturing in the OECD." *Southern Economic Journal*, Vol. 7(2), 2004, pp. 353-376.
- [12] Garver, M. S. and Mentzer, J. T. "Logistics research methods: employing structural equation modeling to test for construct validity." *Journal of Business Logistics*, Vol. 20(1), 1999, pp. 33-57.
- [13] Gerbing, D. W. and Anderson, J. C. "An updated paradigm for scale development incorporating unidimensionality and its assessment." *Journal of Marketing Research*, Vol. 25(2), 1988, pp. 186-192.
- [14] Green Jr., K. W., Whitten, D., and Inman, R. A. "The impact of RFID technology utilization on supply chain productivity and organizational performance." *International Journal of Innovation and Learning*, Vol. 6(2), 2009, pp. 147-162.
- [15] Green Jr., K. W., Whitten, D., and Inman, R. A. "The impact of timely information on organizational performance in a supply chain." *Production Planning and Control*, Vol. 18(4), 2007, pp. 274-282.
- [16] Hatch, D. "Operational performance: what sets best-in-class companies apart?" *Intelligent Enterprise*, Vol. 11(9), 2008, p. 13.
- [17] Holmqvist, M. and Stefansson, G. 2006. "'Smart goods' and mobile RFID: a case with innovation from Volvo." *Journal of Business Logistics*, Vol. 27(2), 2008, pp. 251-272.
- [18] Hozak, K. and Collier, D.A. "RFID as an enabler of improved manufacturing performance." *Decision Sciences*, Vol. 39(4), 2008, pp. 859-881.
- [19] Hsieh, Y., Chiu, H., and Hsu, Y. "Supplier market orientation and accommodation of the customer in different relationship phases." *Industrial Marketing Management*, Vol. 37(4), 2008, pp. 380-393.
- [20] Huckman, R. S. and Zinner, D. E. "Does focus improve operational performance? Lessons from the management of clinical trials." *Strategic Management Journal*, Vol. 29(2), 2008, pp. 173-193.
- [21] Hunt, V. D., Puglia, A., and Puglia, M. *RFID: A Guide to Radio Frequency Identification*, John Wiley & Sons: Hoboken, N.J, 2007.
- [22] Inman, R. A., Sale, R. S., Green Jr., K. W., and Whitten, D. "Agile manufacturing: relation to JIT, operational performance, and firm performance." *Journal of Operations Management*, Vol. 29(4), 2011, pp. 343-355.
- [23] Jalles, J. T. "How to measure innovation? New evidence of the technology-growth linkage." *Research in Economics*, Vol. 64(2), 2010, pp. 81-96.
- [24] Kincade, D., Vass, D., and Cassill, N. "Implementation of technology and relationship to supply chain performance." *International Review of Retail, Distribution, and Consumer Research*, Vol. 11(3), 2001, pp. 301-27.
- [25] Klein, T. and Thomas, A. "Opportunities to reconsider decision making processes due to auto-ID." *International Journal of Production Economics*, Vol. 121(1), 2009, pp. 99-111.
- [26] Kline, R. B. *Principles and Practice of Structural Equation Modeling*, Guilford Press: New York, NY, 1998.
- [27] Kotha, S. and Swamidass, P. M. "Strategy, advanced manufacturing technology and performance: empirical evidence from US manufacturing firms." *Journal of Operations Management*, Vol. 18(3), 2000, pp. 257-277.
- [28] Koufteros, X. A. "Testing a model of pull production: a paradigm for manufacturing research using structural equation modeling." *Journal of Operations Management*, Vol. 17(4), 1999, pp. 467-488.
- [29] Lee, D. and Park, J. "RFID-based traceability in the supply chain." *Industrial Management & Data Systems*, Vol. 108(6), 2008, pp. 713-725.
- [30] Lindell, M. K. and Brandt, C. J. "Climate quality and climate consensus as mediators of the relationship between organizational antecedents and outcomes." *Journal of Applied Psychology*, Vol. 86(1), 2000, pp. 114-121
- [31] Lindell, M. K. and Whitney, D. J. "Accounting for common method variance in cross-sectional research designs." *Journal of Applied Psychology*, Vol. 85(1), 2001, pp. 331-348.

- [32] Lyytinen, K. and Rose, G. M. "How agile is agile enough? Toward a theory of agility in software development." *Business Agility and Information Technology Diffusion*, edited by Baskerville, R. L., Mathiassen, L., Pries-Heie, J., and DeGross, J.I. Springer Science+Business Media, Inc.: New York, NY, 2005.
- [33] Mabin, V. J., and Balderstone, S. J. "The performance of the theory of constraints methodology: analysis and discussion of successful TOC applications." *International Journal of Operations & Production Management*, Vol. 23(6), 2003, pp. 568-595.
- [34] Malhotra, N. K. Patil, A., and Kim, S. S. "Bias breakdown." *Marketing Research*, Vol. 19(1), 2007, pp. 24-29.
- [35] Marsch, H. W. and Hocevar, D. "Application of confirmatory factor analysis of the study of self-concept: first and higher order factor and their invariance across groups." *Psychological Bulletin*, Vol. 97(3), 1985, pp. 562-582.
- [36] Narasimhan, R., Swink, M., and Kim, S. W. Disentangling leanness and agility: An empirical investigation. *Journal of Operations Management*, Vol. 24(5), 2006, pp. 440-457.
- [37] Neuwirth, D. "Transforming your equipment management process with RFID." *Healthcare Purchasing News*, Vol. 29(6), 2005, p. 82.
- [38] Olhager, J. and Sellidin, E. "Enterprise resource planning survey of Swedish manufacturing firms." *European Journal of Operational Research*, Vol. 146(2), 2003, pp. 365-373.
- [39] Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., and Podsakoff, N. P. "Common method biases in behavioral research: a critical review of the literature and recommended remedies." *Journal of Applied Psychology*, Vol. 88(5), 2003, pp. 879-903.
- [40] Podsakoff, P. M. and Organ, D. W. "Self-reports in organizational research: problems and prospects." *Journal of Management*, Vol. 12(4), 1986, pp. 531-544.
- [41] Prater, E., Frazier, G. V., and Reyes, P. M. "Future impacts of RFID on e-supply chains in grocery retailing." *Supply Chain Management*, Vol. 10(2), 2005, pp. 134-142.
- [42] Rai, A., Patnayakuni, R., and Seth, N. "Firm performance impacts of digitally enabled supply chain integration capabilities." *MIS Quarterly*, Vol. 30(2), 2006, pp. 225-246.
- [43] Ramamurthy, K., Premkumar, G., and Cru, M. R. "Organizational and interorganizational determinants of EDI diffusion and organizational performance: a causal model." *Journal of Organizational Computing and Electronic Commerce*, Vol. 9(4), 2000, pp. 253-285.
- [44] Richardson, H. A., Simmering, M. J., and Sturman, M. C. "A tale of three perspectives." *Organizational Research Methods*, Vol. 12(4), 2009, pp. 762-800.
- [45] Sarac, A., Absi, N., Dauzère-Pérès, S. "A literature review on the impact of RFID technologies on supply chain management." *International Journal of Production Economics*, Vol. 128(1), 2010, pp.77-95.
- [46] Sari, K. "Exploring the impacts of radio frequency identification (RFID) technology on supply chain performance." *European Journal of Operational Research*, Vol. 207(1), 2010, pp. 174-183.
- [47] Sharifi, H. and Zhang, Z. "Agile manufacturing in practice: application of a methodology." *International Journal of Operations and Production Management*, Vol. 21(5/6), 2001, pp. 772-794.
- [48] Spector, P. E. "Method variance as an artifact in self-reported affect and perceptions at work: myth or significant problem?" *Journal of Applied Psychology*, Vol. 72(3), 1987, pp. 438-443.
- [49] Spiegel, R. News and trends. *Supply Chain Management Review*, Vol. 9(4), 2005, pp. 63-64.
- [50] Stambaugh, C. T. and Carpenter, F. W. "Wireless innovation in inventory monitoring and accounting." *Strategic Finance*, Vol. 91(6), 2009, pp. 35-40.
- [51] Stank, T. P. and Lackey, C. W. "Enhancing performance through logistics capabilities in Mexican maquiladora firms." *Journal of Business Logistics*, Vol. 18(1), 1997, pp. 91-123.
- [52] Swafford, P. M., Ghosh, S., and Murthy, N. "Achieving supply chain agility through IT integration and flexibility." *International Journal of Production Economics*, Vol. 116(2), 2008, pp. 288-297.
- [53] Tang, C. and Tomlin, B. "The power of flexibility for mitigating supply chain risks." *International Journal of Production Economics*, Vol. 116(1), 2008, pp. 12-27.
- [54] Vance, A. "An empirical investigation of the potential of RFID technology to enhance supply chain agility." *Business Agility and Information Technology Diffusion*, edited by Baskerville, R. L., Mathiassen, L., Pries-Heie, J., and DeGross, J. I. Springer Science+Business Media, Inc.: New York, NY, 2005.
- [55] Zelbst, P. J., Sower, V. E., and Green Jr., K. W. "An experiential approach to develop understanding of RFID technology." *International Journal of Management in Education*, Vol. 2(4), 2008, pp. 419-431.
- [56] Zelbst, P. J., Green, K. W., Abshire, R.D., and Sower, V. E. "Relationships among market orientation, JIT, TQM, and agility." *Industrial Management & Data Systems*, Vol. 110(5), 2010, pp. 637-658.
- [57] Zhou, W. "RFID and item-level information visibility." *European Journal of Operational Research*, Vol. 198(1), 2009, pp. 252-258.