IMPACT OF RFID AND INFORMATION SHARING ON JIT, TQM, AND OPERATIONAL PERFORMANCE

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ABSTRACT

From a systems perspective, our research focuses on the effects of RFID technology adoption and information sharing within a manufacturing facility on the JIT and TQM practices and the subsequent impact on operational performance of manufacturing firms. Data were collected from 104 manufacturing managers, supervisors, and quality professionals and analyzed using a path analysis methodology. RFID technology utilization and information sharing combine to enhance a manufacturing organization's JIT and TQM capabilities which lead to improved operational performance. Although the sample size is large enough to support path analysis, it is not of sufficient size to support structural equation modeling. This limitation precludes assessing the model as a whole. Direct and indirect effects are assessed, however. Manufacturing managers are provided with a framework for assessing the synergistic impact of combining RFID technology and information sharing on the JIT and TQM capabilities and the subsequent impact on the operational performance.

INTRODUCTION

"Everything we do in today's manufacturing environment generates a multitude of data from a variety of sources." (Hull, 2011, p. 43) Automated data entry reduces the potential for errors in data collection because human interaction is minimized. Radio Frequency Identification (RFID) is a technology that will allow organizations to automate data collection. In addition, RFID allows for data to be shared within systems. This information can help manufacturing subsystems such as just-in-time (JIT) and total quality management (TQM) to operate more efficiently (Hull, 2011).

From a systems theory perspective all subsystems within the operations function should be integrated and coordinated to achieve competitive advantage that is reflected in improved operational performance. We argue that RFID technology utilization and information sharing facilitate integration and coordination which in turn impact an organization's JIT and TQM improvement efforts. The JIT and TQM improvement efforts as a result will help the organization's operating performance. We theorize a structural model and assess the model following a traditional path analysis approach using data collected from a national sample of manufacturing managers.

In the following section, a theoretical model is presented and theoretically and empirically justified through a review of the literature and discussion of the hypotheses incorporated in the model. A discussion of the methodology employed in the study is then presented followed by a description of the scale assessment and the path analysis results incorporating analysis of direct and indirect effects. Finally, a conclusion section incorporating discussions of the contributions of the study, limitations of the study, recommendations for future research, and managerial implications follows.

LITERATURE REVIEW AND HYPOTHESES

Systems theory

According to Hull (2011), once changes are made internally to an organization requests for other changes will grow exponentially. This is a clear indication that organizations are systems. Hull goes on to say that there needs to be a system of tracking with unique identifiers to control all of the changes. While this author is referring to an overall system the principle can be applied to subsystems within an organization. It is also implied from Hull's perspective that success is tied directly to the organizations ability to share information in systems thus providing subsystems, such as JIT and TQM, with the information necessary to increase the overall organizations operational performance. As such, a systems theory perspective is adopted to assess the combined impact of a RFID technology utilization and information sharing on manufacturing improvement programs, Just-in-Time (JIT), Total Quality Management (TQM), and operational performance within the manufacturing sector.

Organizations can be looked at as living entities (De Geus, 1997). Decision makers within subsystems of the organization are dependent upon information to direct activities towards the organization's goals. Information creates boundaries for the organization (Miller, 1978). For example, the accuracy and the timing of the receipt of information can impact operational performance of the organization. The process of information sharing is the key element for JIT and TQM in an organization. RFID utilization is thought to improve the information sharing process through both timing and accuracy resulting in better operational performance.

Theoretical model

RFID is theorized as positively impacting information sharing. Both RFID and information sharing are theorized as positively impacting JIT and TQM practices. JIT is theorized as positively impacting TQM, and both JIT and TQM are theorized as positively impacting operational performance. Generally, the model depicts a system in which RFID technology utilization combines with information sharing capabilities to support both JIT and TQM practices ultimately leading to improved operational performance. The model incorporates eight associations all of which are hypothesized as positive.

Hypotheses

According to Hozak and Collier (2008), RFID can enable factory automation and better performance along several dimensions in manufacturing. RFID is an important technology for improving efficiency and effectiveness in both production and operations of manufacturing organizations according to Irani *et al.* (2010). Research suggests that there are three basic categories that manufacturing should consider using RFID to improve performance, data collection, data dependencies, and visibility (Brintrup *et al.*, 2010).

RFID technology utilization reflects the degree to which manufacturers have adopted RFID technology to track all types of inventory through organizational and supply chain processes (Green *et al.*, 2009). Ramudin *et al.* (2008) investigate the use of an RFID-based control system as it applies to maintenance, repair and overhaul activities in an aircraft engine manufacturing company and suggest that organizations should take advantage of the full potential of the technology.

The use of RFID as part of an organization's infrastructure has the potential benefits of allowing for more effective and efficient decision making using real time data, performing routine and manual task better while reducing cost or possibly even reducing the need for those tasks, and allowing top management better visibility of operational transactions (Kim *et al.*, 2010). In other words, RFID utilization facilitates the information sharing infrastructure's ability to capture real-time information throughout an organization allowing for better JIT and TQM systems resulting in improved operational performance. According to Zelbst *et al.* (2010b), the adoption of RFID technology allows for improved information sharing between supply chain members. This research is investigating to determine if RFID utilization enhances information sharing to improve JIT and TQM resulting in improved operational performance.

Zelbst *et al.* (2010b) defined information sharing as supply chain partners mutually and openly sharing information. We focus on the manufacturing organization's ability to share information with immediate customers and suppliers. The information gathered and shared through the use of RFID could result in cost reductions in labor productivity, automation, waste and returns (Collins, 2004). According to Zelbst *et al.* (2010b), RFID-enhanced information sharing results in improved supply chain performance. In addition, the direct impact of RFID technology utilization on operational performance has been investigated (Zelbst *et al.*, 2010c). This study investigates the impact of RFID utilization on information sharing.

H1: RFID technology utilization positively affects information sharing.

RFID is seen as a method of achieving leaner manufacturing through real time data and production and inventory visibility (Brintrup *et al.*, 2010). JIT is an improvement program aimed at eliminating all forms of waste from all organizational processes (Vokurka and Lummus, 2000). Uncertainty and variation are forms of waste that are particularly detrimental to JIT activities (Sower and Bimmerle, 1991). Among other things, JIT advocates the utilization of smaller lot sizes and minimization of safety stock. In order for this to work effectively, lots in transit from suppliers and inventory within the organization must be carefully tracked. RFID provides the capability for near real-time tracking of lots thus facilitating JIT activities. RFID tagged materials can be inventoried quickly and easily so that uncertainty about levels of inventory stocks is greatly reduced.

Guanghui *et al.* (2011) studied RFID utilization as a method of JIT implementation using case study methodology. The results were focused on material delivery. Mercedes-Benz uses RFID to track vehicle production to keep JIT deliveries on time and to notify suppliers of any changes in their production schedule (Krizner, 2000). By providing up-to-date information about inventory levels and location, RFID allows the manufacturer to immediately notify their suppliers when materials are needed. This use of RFID allows for faster signaling for production control, helps to lower lot sizes, reduces setup time, and reduces stoppages for quality. As a result, we hypothesize:

H2: RFID technology utilization positively affects Just-in-Time practices.

According to Haynes *et al.* (1991), proper implementation of JIT in manufacturing must be preceded by timely information sharing. The two major flows in a JIT supply chain system are materials and information. Variation, inaccuracies, and long lead times in either stream negatively impact the operation of the system. Accurate and timely information flows throughout the supply chain are essential to JIT performance. Short cycle times for both information and materials are vital to JIT performance. According to Handfield and Nichols, (1999, p. 56), supply chain cycle times are often lengthy "due to the time needed to gather the information required to make the decisions."

H3: Information sharing positively affects Just-in-Time practices.

Oakes and Westcott (2001) define TQM as "a customer driven, process improvement approach to management." Quality information systems which collect, process, store, and transmit data and information throughout the system support the overall quality system in achieving its goals (Sower, 2011). The quality and timeliness of the data provided to TQM decision makers affects the quality of their decisions. Myers (2005) reported that studies have shown that fewer than half of the users of management information systems are happy with the quality of the information they receive. The ability of RFID to provide near-real time data from more sources within the supply chain that is more accurate than more manual systems provides the basis for this technology to increase the timeliness and accuracy of information available to TQM decision makers.

H4: RFID technology utilization positively affects Total Quality Management practices.

H5: Information sharing positively affects Total Quality Management practices.

There is little controversy about the synergistic relationship between JIT and TQM. In his groundbreaking book, Schonberger (1982) stressed that JIT and TQM must be considered together and as such they form a multifaceted manufacturing system. Sower and Bimmerle (1991) suggest that quality practices that reduce variation in the system are necessary for the success of JIT. In turn, JIT practices which reduce lead times and cycle time variation affect TQM practices and can improve overall performance of the system. A recent study which examined market orientation, Zelbst, *et al*. (2010a) found that JIT positively and directly influences TQM.

H6: Just-in-Time practices positively affect Total Quality Management practices.

Operational performance is defined by Feng *et al.* (2006, p. 26) as, "the performance related to organizations' internal operations, such as productivity, product quality and customer satisfaction." Simulation studies (Sower *et al*., 1993) have demonstrated the effect of JIT practices such as variation reduction in process times, use of preventative maintenance, and source inspection on improvement in operational performance factors such as inventory levels and throughput. The ability of JIT systems to produce small lots with short lead times provides the ability to decrease customer response time. Inman *et al.* (2011) found JIT-purchasing to be positively associated with operational performance.

H7: Just-in-Time practices positively affect operational performance.

Researchers have linked operational success with TQM factors such as management commitment, open communication, employee empowerment, and employee involvement with quality (Powell, 1995; Yusof and Aspinwall, 2000). Manimaran (2020) found a positive relationship between TQM service quality factors and customer satisfaction. Tanninen *et al.* (2010) documented a relationship between TQM practices and operational performance as measured by customer satisfaction and productivity. Their study found that the effect increased the longer a TQM program had been in place.

H8: Total Quality Management practices positively affect operational performance.

METHODOLOGY

Sample

Data from a sample of 104 manufacturing managers, supervisors, and quality professionals working for U.S. manufacturers were collected via an on-line data service (Zoomerang through MarketTools, Inc.) during the winter of 2008-2009. Eighty (77%) respondents selected one of 18 different manufacturing categories their firm belongs. Fabricated metal products (14.4%), food and kindred products (10.6%), electronic and other electrical equipment (7.7%), transportation equipment (6.7%), and printing/publishing and allied industries (6.7%) are the most frequently represented manufacturing categories. The remaining 24 (23%) respondents selected the more general category "other manufacturing." Thirty-one percent of the respondents hold managerial positions, 54% hold supervisory positions, and 15% are quality professionals. Respondents had an average 9.1 years in their current positions and work for organizations with an average of 495 employees. The sample represents a relatively diverse group of manufacturers. It should be noted that due to financial constraints it was only possible to contact potential respondents once, precluding assessment of potential non-response bias.

Measurement of Constructs

The structural model under investigation incorporates five constructs: RFID technology utilization, information sharing, JIT, TQM, and operational performance. The RFID technology utilization scale was originally developed and assessed by Green *et al.* (2009). The operational performance scale is taken from Zelbst *et al.* (2010c). Information sharing reflects the ability to synchronously share real-time information with immediate customers and suppliers and is measured with a multi-item scale previously developed and assessed by Green *et al.* (2007). The JIT and TQM scales are taken from Flynn *et al.* (1995). These scales incorporate multiple dimensions. The JIT measurement scale is comprised of kanban, lot size reduction, setup time reduction, and JIT scheduling dimensions. The TQM scale incorporates customer focus, product design, and statistical process control dimensions. The scales are attached in Appendix 1.

Statistical Analysis

All measurement scales were assessed for unidimensionality, reliability and validity and for common method bias. Summary variables were computed and descriptive statistics and correlations computed. A path analysis was completed and direct and indirect effects determined. A traditional path analysis approach (Kline 1998) is adopted rather than a more robust structural equation modeling approach due to the relatively small sample size available. Hair *et al.* (2006) argue that sample sizes from 150 to 400 are generally suitable for structural equation modeling analysis with sample size varying according to the complexity of the model and the number of parameters to be estimated. In this case, the five measurement scales included 52 total measurement items with treating the JIT and TQM scales as second order scales reducing the number of items in the analyses to 33. Considering this large number of items relative to the sample size, it was decided that the traditional approach to path analysis is the better suited method of analysis.

RESULTS

Measurement Scale Assessment

Table 1 displays the results of the assessments for unidimensionality, reliability, convergent validity, and discriminant validity of the study scales. The JIT and TQM scales are assessed as second-order scales. Each of these multi-dimensional scales was first subjected to confirmatory factor analysis to demonstrate the underlying factors. Some items in each of the scales were necessarily removed. Those items are identified in Appendix 1. The remaining items in each of the dimensions were then averaged and those averages used as second-order measures of JIT and TQM.

When sample size is relatively small, as it is in this case, Koufteros (1999) recommends the use of relative chi-square, non-normed fit index (NNFI), and comparative fit index (CFI) values to assess unidimensionality and convergent validity. Relative chi-square values of less than 2.00 and NNFI and CFI values greater than .90 indicate reasonable fit (Koufteros, 1999). Results indicate that all NNFI and CFI values are greater than .90 as recommended. The relative chi-square values for RFID technology utilization and information sharing are higher than the recommended value of 2.00 but are well below the 5.00 level recommended by Marsch and Hocevar (1985). Assessment for discriminant validity requires a chi-square difference test for each pair of scales, with a statistically significant difference in chi-squares indicating validity (Garver and Mentzer, 1999). All possible pairs of the study scales were subjected to chi-square difference tests with each pairing producing a statistically significant difference. Cronbach's coefficient alpha is used to assess the internal reliability of the scales. Alpha values for all study scales exceed the .70 level recommended by Garver and Mentzer (1999) indicating sufficient reliability.

As Koufteros (1999) recommends, the scales are further assessed within the context of the full measurement model using a confirmatory factor analysis methodology. The measurement model fits the data relatively well with a relative chi-square value of 1.19, an RMSEA value of 0.04, a CFI value of .97, and an NNFI value of 0.97. A review of the standardized residual matrix identified only four pairs with absolute values greater than 4.00.

Common method variance assessment from RFID Agile Paper

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 (Richardson *et al.*, 2009). 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 (Crampton and Wagner, 1994; Spector, 1987). To alleviate concerns related to common method bias, we took precautions recommended by Podsakoff *et al.* (2003) when constructing the survey instrument. Specifically, we incorporated scale items that are simple and unambiguous, formatted the survey such that scales representing dependent constructs appeared before those representing independent constructs (operational performance before JIT and TQM), separated the RFID technology utilization scale from the information sharing scale and separated the JIT and TQM scales from the operational performance scale by other scales, used various instruction sets and anchor combinations for the study scales, and took steps to ensure respondent anonymity.

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 (Podsakoff and Organ, 1986). As prescribed by Harman's test, all variables were entered into a factor analysis. Results of the factor analysis (maximum likelihood, varimax rotation) of all scale items revealed 10 factors with eigenvalues greater than one, which combined to account for 73% of the total variance. While the first factor accounted for 39% 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, Lindell and Brandt (2000) recommend that the smallest correlation among the variables be used as a proxy for common method variation. Following this approach, the smallest correlation is .30 between RFID technology utilization and operational performance. The second smallest correlation is .36 for JIT and operational performance. Substitution of these correlations into the formulas provided by Malhotra *et al.* (2007) yields a computed z-score of 2.06. This computed z-score corresponds with significance at the .039 level. Adjusting for common method variance using the smallest correlation (.30), the second smallest correlation (.36) 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 (Podsakoff and Organ, 1986; Lindell and Whitney, 2001).

Descriptive Statistics and Correlations

Summary variables were computed by averaging item values for the RFID technology utilization, information sharing, and operational performance and for the JIT and TQM dimensions. Because the JIT and TQM scales include multiple dimensions, the means for the dimensions were subsequently averaged to compute JIT and TQM summary variables. All variables are sufficiently normally distributed with skewness and kurtosis statistics between -2.00 and +2.00. All correlations are positive and significant at the .01 level.

Path analysis results

Because the sample size is insufficient to support structural equation modeling, a path analysis methodology (Kline, 1998) was used to assess the direct and indirect effects incorporated in the theorized model (Figure 1). Three multiple linear regressions and one simple linear regression were conducted to assess the direct effects illustrated in the theorized model. Table 3 displays the results of the regression analyses including both unstandardized and standardized coefficients, coefficients of determination (R^2), proportions of unexplained variances ($1-R^2$) for each of the endogenous variables, and variance inflation factor (VIF) values. All VIF values are well below 10 indicating that multicolinearity is not a problem (Hair *et al.*, 2006).

Table 1: Regressions to Generate Path Coefficients

Criterion	Predictors	Unstandardized Coefficients[a]	Standardized Coefficients	R^2	$1 - R^2$	VIF
1. OP	JIT	.046ns (.090)	.056 ns	.266	.734	1.655
	TQM	.448** (.143)	.479**			1.655
2. TQM	RFID	.065 ns (.058)	.100ns	.504	.496	1.594
	IS	.369** (.097)	.387**			2.083
	JIT	.279** (.085)	.319**			1.892
3. JIT	RFID	.151 * (.066)	.204 *	.471	.529	1.516
	IS	.596** (.097)	.548**			1.516

4. IS	RFID	.399** (.055)	.583**	.340	.660	1.000

[a] Values in parentheses are standard errors.
** significant at the 0.01 level (2-tailed)
* significant at the 0.05 level (2-tailed)
ns non-significant

Table 2 displays the results of an effects decomposition based upon the standardized coefficients presented in Table 1. RFID technology utilization directly and positively affects information sharing (hypothesis 1) and JIT (hypothesis 2) but does not directly affect TQM (hypothesis 4). Information sharing directly and positively affects both JIT (hypothesis 3) and TQM (hypothesis 5). JIT directly and positively affects TQM (hypothesis 6) but does not directly affect operational performance (hypothesis 7). TQM directly and positively affects operational performance (hypothesis 8). RFID technology utilization indirectly affects both JIT and TQM through information sharing. Information sharing indirectly affects TQM through JIT and operational performance through TQM. JIT indirectly affects operational performance through TQM.

Table 2: Decomposition of Standardized Effects

Independent Variables	IS	JIT	TQM	OP
RFID				
Direct effect	.583**	.204 *	.100ns	
Indirect via IS		.319**	.226**	
Indirect via JIT			.065ns	.011ns
Indirect via TQM				.048ns
IS				
Direct effect		.548**	.387**	
Indirect via JIT			.175**	.031ns
Indirect via TQM				.185 *
JIT				
Direct effect			.319**	.056ns
Indirect via TQM				.153 *
TQM				
Direct effect				.479**
R^2	.340	.471	.504	.266

** significant at the 0.01 level (2-tailed)
* significant at the 0.05 level (2-tailed)
ns non-significant

Figure 2 displays the path model with beta and R^2 values. The results show that adoption of RFID technology in combination with information sharing capabilities supports JIT and TQM improvement efforts which in turn yield improved operational performance for firms in the manufacturing sector. Information sharing mediates the impact of RFID technology on JIT and TQM, and TQM mediates the impact of information sharing and JIT on operational performance.

CONCLUSIONS

We adopt a general systems perspective and investigate the linking of RFID technology utilization and information sharing capabilities with operations programs (JIT and TQM) on operational performance in the manufacturing sector. Manufacturing organizations with information sharing capabilities, such as those available through established ERP systems, are more likely to benefit from RFID technology adoption. The impact of RFID technology on TQM improvement programs is fully mediated through information sharing, and the impact of RFID technology on JIT improvement programs is partially mediated. Without established information sharing capabilities, manufacturers will not see the full benefit of investments in RFID technology. It is best, then, to incorporate the use of RFID technology within the context of an established functional ERP system that supports information sharing with suppliers and customers. RFID technology coupled with ERP systems enable manufacturers to become more efficient by eliminating wastes associated with managing raw materials, work in process, and finished goods inventories. RFID technology incorporated within existing ERP systems also enable manufacturers to better satisfy customers in terms of product quality and delivery responsiveness. This improved efficiency coupled with improved effectiveness result in improved operational performance. Considering the significant empirical evidence support a positive relationship between operational performance and organizational performance, we argue that RFID technology coupled with ERP systems will enhance efforts to improve efficiency and effectiveness and ultimately organizational performance.

Limitations of the study

While we believe that we have been successful in accomplishing the objectives of the study, there are limitations that should be noted. The data collection methodology had only one wave disallowing subsequent assessment for non-response bias. The study would be stronger had two or three waves been incorporated. Time and financial resources precluded additional survey waves, however. While the sample size is sufficient to support traditional path analysis, it is insufficient to support more sophisticated structural equation modeling analysis. This limitation precludes assessment of the model as a whole. Only direct and indirect effects can be assessed.

Future research

We believe that this study is in the first wave of empirical investigations of the role of RFID technology utilization within organizational and supply chain contexts. Future research is necessary to replicate the study. Additionally, a larger sample size is necessary to fully investigate the model fit following a structural equation modeling methodology. There is also the need to expand the model to include other measures related to organizational performance, supply chain management, and supply chain performance.

Implications for practitioners

The contribution of this study lies in the assessment of the impact of a system incorporating the components of RFID technology utilization, information sharing, JIT, and TQM on operational performance. While several of the individual hypotheses identified in the study model have been previously investigated, the total system incorporated in the model has not been previously investigated. Essentially, we have argued that the incorporation of RFID technology within an existing system with ERP, JIT, and TQM subsystems will incrementally improve the operational performance of the organization. The results of this systems-based investigation provide manufacturing practitioners with valuable direction. Successful implementation of RFID technology within the manufacturing sector depends upon existing ERP systems and JIT and TQM improvement programs.

References and Appendices are available upon request from Pamela J. Zelbst