Impact of information sharing and green information systems

Jeramy Meacham
Department of Management, Marketing, and Management Information Systems, College of Business, Southern Arkansas University, Magnolia, Arkansas, USA

Lisa Toms
College of Business, Southern Arkansas University, Magnolia, Arkansas, USA, and

Kenneth W. Green Jr and Vikram S. Bhadauria
Department of Management, Marketing, and Management Information Systems, College of Business, Southern Arkansas University, Magnolia, Arkansas, USA

Abstract

Purpose – This paper aims to theorize and assess a structural model that depicts the impact of an organization's capability to share information with supply chain partners through a focused green information system for the purpose of improving environmental performance.

Design/methodology/approach – Data were collected from 159 manufacturing managers and analyzed using a structural equation modeling methodology.

Findings – The general capability to share information with supply chain partners coupled with the specific capabilities of green information systems enhances environmental performance. Green information systems serve as a partial mediator to the relationship between supply chain information sharing and environmental performance.

Research limitations/implications – While environmental sustainability has implications for all categories of supply chain partners, the study sample focuses on the manufacturing sector only.

Practical implications – Evidence supports the need for manufacturers to develop information sharing and green information system capabilities to improve environmental performance.

Originality/value – This is one of the first studies to empirically assess the role of information systems in achieving environmental sustainability. The results of this investigation support the proposition that information sharing among supply chain partners is a key to achieving environmental sustainability.

Keywords Information sharing, Green information systems, Environmental performance, Information management, Information systems

Paper type Research paper

1. Introduction

Sustainable supply chain management requires consideration of economic performance, social performance, and environmental performance. The streams of research related to the impact of management strategies and practices on economic performance and social performance are somewhat well developed. The research focus has more recently turned to development and investigation of environmental sustainability models in an effort to determine how best to improve environmental performance.

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In line with this recent trend, we investigate the impact on environmental performance of an organization's ability to share information through established enterprise resource planning (ERP) systems that have been modified to monitor environmental initiatives and outcomes.

Melville (2010) and Watson *et al.* (2010) argue that the role of information systems within the context of environmental sustainability is not sufficiently developed and that there is little research focused on how best to use information systems to improve environmental performance. Toward that end, our purpose is to empirically establish the relationships between an organization's ability to share information and the degree to which an organization has modified its information system to focus on environmental concerns on the environmental performance of the organization. Generally, we propose that a manufacturing organization's ability to synchronously share real-time information with suppliers and customers and the implementation of green information systems combine to positively impact the manufacturing organization's environmental performance. A theoretical model that incorporates information sharing as antecedent to green information systems and environmental performance as the final consequence is developed and empirically assessed using data collected through an on-line data collection service from a sample of manufacturing managers working for US manufacturing organizations. Non-response bias and common method bias are assessed, and all measurement scales are fully assessed for validity and reliability. Measurement and structural models are assessed through structural equation modeling practices.

The literature review section follows and includes a review of the related literature, a description of the proposed theoretical model, and support for the study hypotheses. The sampling process, sources of the measurement scales, and a delineation of the statistical analyses employed to assess the measurement scales and study hypotheses are presented in the methodology section. The results section includes a demographic description of the sample, results of the assessment of measurement scale reliability and validity, results of the assessments of non-response bias and common method bias, and results of the assessment of the measurement and structural models. In the final section, conclusions, limitations, future research, and implications for management practitioners are discussed.

2. Literature review

Adoption of environmental sustainability as a strategic imperative requires that organizations develop and implement green information systems. A strategic focus on green supply chain management necessitates the need to monitor manufacturing, purchasing, and selling processes to ensure environmental sustainability (Preuss, 2002). Information systems are not just enablers of interconnectedness; they can also be used to enhance trust and commitment among the supply chain partners (Welty and Becerra-Fernandez, 2001).

The successful implementation of environmental improvement programs depends on the capability of the organization's information systems to capture data related to the environmental sustainability efforts and outcomes of the organization's manufacturing, purchasing, selling, and logistics processes (Preuss, 2002). Green information systems represent the backbone of environmental management efforts by supporting the firm's internal environmental management systems and by meeting the reporting needs for various stakeholders (El-Gayar and Fritz, 2006). Green information systems provide the information needed for coordinating with customers in terms of eco-design, production, packaging, transportation, recycling, disposal, and scrap ratio.

Information sharing, through the use of green information systems, is a key enabler for supply chain management in terms of integration and coordination (Chandra *et al.*, 2007). Frohlich and Westbrook (2001) propose that the concept of logistical integration includes the extent of cooperation in managing basic informational and material flows along the supply chain. Based on a case study of the food industry, Hamprecht *et al.* (2005) argue the importance of incorporating environmental controls with other quality controls within the information system that extends throughout the food supply chain. Green information systems provide the information necessary to make decisions about eco-design, in terms of material and energy consumption, reuse, recycling and recovery of materials.

ERP systems provide the infrastructure necessary for manufacturing organizations to share information with suppliers and customers. Well designed and successfully implemented ERP systems supply operational, tactical, and strategic information among manufacturers, suppliers and customers (Siau and Tian, 2004; Morash and Clinton, 1997). Rajagopal (2002) describes the value of ERP systems as providing "one single information" that is available to all supply chain members. This "one single information" is accessed seamlessly (Siau and Tian, 2004) in real-time (Gefen and Ragowskyrik, 2005). Operational, tactical, and strategic information that can be accessed seamlessly and in real-time enables a necessary end-to-end connectivity (Rajagopal, 2002).

The seamless, real-time characteristics of ERP systems support the provision of quality information to supply chain partners in the right form, in the right place, and at the right time (Green *et al.*, 2007). Customer demand for information is no longer required to work its way from the customer sequentially through multiple information systems resulting in time delays and distortion (Cigolini *et al.*, 2004).

Existing ERP systems facilitate the synchronous sharing of real-time information among supply chain partners (suppliers, manufacturers, retailers, wholesalers, customers). Green information systems extend this existing ability to share information to specifically include information related to environmental improvement programs and environmental outcomes. The architecture of ERP systems includes a centralized database containing transaction and operations data that is accessed and analyzed using ERP software and business application programming interfaces developed by ERP software vendors and third-party software vendors. Data related to sustainability efforts and outcomes are captured from sustainability processes and the resulting sustainability-related information displayed through additional sustainability application programming interfaces. The combination of information sharing capabilities with the implementation of green information systems should, therefore, lead to improved environmental performance. It is our purpose to investigate, within a manufacturing context, the impact of the ability to share information coupled with the implementation of green information systems on environmental performance.

The definition of information sharing is derived from Green *et al.* (2007) and Zelbst *et al.* (2010). The definition of environmental performance is operationally developed from the scale developed by Zhu *et al.* (2008). The definition for green information systems is derived from the characteristics of such systems developed by Esty and Winston (2006).

Information sharing is the ability to synchronously share real-time information with suppliers and customers (Green *et al.*, 2007; Zelbst *et al.*, 2010). Green *et al.* (2007) discuss the ability to openly share information with suppliers and customers in a timely manner. The information is available to all supply chain partners as needed on a real-time basis. Generally, both Green *et al.* (2007) and Zelbst *et al.* (2010) acknowledge that this type of information is made available through established ERP systems.

Green information systems are information systems that are used to monitor processes to ensure environmental sustainability (Esty and Winston, 2006; Watson *et al.*, 2008). Such information systems are used to track environmental information, reduce energy consumption, and monitor emissions and waste production (Esty and Winston, 2006). Further, green information systems provide information that encourages green choices by consumers, improve decision making by executives related to sustainability issues, support the generation and distribution of renewable energy, and identify the role of information systems in energy policy (Esty and Winston, 2006).

Environmental performance relates to the ability of manufacturing plants to reduce air emissions, effluent waste, and solid wastes (Zhu *et al.*, 2008). Additionally, it focuses on the plant's ability to decrease consumption of hazardous and toxic materials and to decrease the frequency of environmentally related accidents (Zhu *et al.*, 2008).

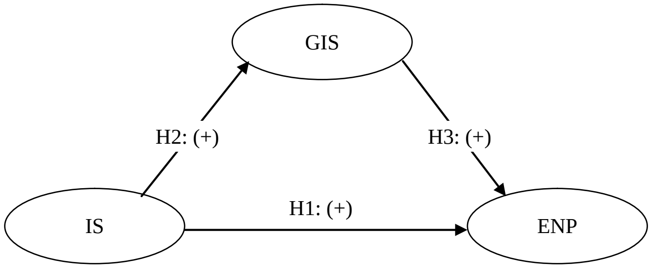
The literature review did not reveal any prior empirical assessments of the specific study hypotheses. We believe that this study is in the first wave of empirical examinations of the role of information systems in developing and maintaining environmental sustainability. There is anecdotal evidence that information sharing and green information systems improve environmental performance.

Lee *et al.* (2004) identify Wal-Mart as one of the first to develop and implement an ERP system spending $4 billion to build the proprietary Retail-Link system. With this established ERP system, Wal-Mart has expanded the system to extend and monitor environmental sustainability efforts throughout its supply chain. Wal-Mart is working with the Sustainability Consortium to develop environmental standards and an environmental rating system for suppliers (Weise, 2011) and, as a result, reduced carbon emissions by 2,600 tons (Smith, 2009).

Global companies, such as Caterpillar Inc., with long established ERP systems (Harrington, 1997), have added capabilities to those systems that facilitate data capture, monitoring, and reporting on progress toward environmental goals. Caterpillar's *2011 Sustainability Report* illustrates the extensive reporting of progress toward environmental goals such as a 25 percent improvement in energy efficiency, a 25 percent reduction in greenhouse gas emissions, complete elimination of waste, and holding water consumption flat (Caterpillar Inc., 2011). The case is made that Caterpillar combined the information sharing capabilities of its ERP system with additional green information systems features to improve its environmental performance.

2.1 Theoretical model

Figure 1 shows the theoretical model and individual study hypotheses. To assess the mediating impact of green information systems, it is necessary to establish a link between information sharing and environmental performance (*H1*). It is then necessary to introduce green information systems as a mediator by establishing a link between information sharing and green information systems (*H2*) and a link between green information systems and environmental performance (*H3*). The mediating effect



Notes: *H4*: IS indirectly impacts ENP through GIS (mediation); IS – information sharing, GIS – green information systems, ENP – environmental performance

Figure 1. Theoretical model with hypotheses

of green information systems is demonstrated if *H1-H3* are positive and significant and if the coefficient for *H1* is significantly reduced following the introduction of green information systems.

2.2 Hypotheses

Barratt and Oke (2007) argue that the ability to share information among supply chain partners develops a "distinctive visibility" that is "valuable, rare, imperfectly mobile, not imitable, and not substitutable." Solér *et al.* (2010) further argue that such distinctive visibility has the potential for creating improved environmental performance and a strong competitive advantage based on environmental sustainability. Thus, the ability to share information with suppliers and customers through established ERP systems supports an organization's environmental performance (Solér *et al.*, 2010). This ability ensures that all supply chain partners are aware of environmental efforts and outcomes and the impact of those efforts and outcomes on the manufacturer's environmental performance. The sharing enables support from suppliers for environmental sustainability efforts by manufacturers and ensures that the environmental outcomes are not sub-optimized elsewhere in the supply chain. Without the ability to share information, partners within a supply chain may be working at cross-purposes as they attempt to improve the environmental performance at both the organizational and supply chain levels. No existing empirical studies that statistically relate information sharing with environmental performance were found:

H1. Information sharing is positively associated with environmental performance.

Melville (2010) emphasizes the need for expanding research efforts investigating the role of information systems in support of environmental sustainability. Information systems must be modified to facilitate informing and motivating organizational stakeholders and partners of the urgent need to adopt environmentally friendly practices and to assess the environmental impact of such practices (Melville, 2010). Stokes and Tohamy (2009) identify the ability to gather data and share information in real-time as one of the fundamental operational traits of green supply chains. Firms seeking certification under the ISO 14,001 environmental standards are required to have a system for measuring and monitoring environmental impacts (Berthelot and Coulmont, 2004; Graves, 2003). Hamprecht *et al.* (2005) argue that controls for environmental performance be integrated with those for process and product management.

No empirical studies that specifically assessed the relationship between information sharing and green information systems were found during the literature review. The ability to establish a green information system that supports the monitoring of environmental sustainability efforts and outcomes depends upon the existence of an established ERP system that facilitates the general ability to share information synchronously and in real-time. These general information sharing capabilities serve as the foundation for the more focused capabilities of green information systems to inform supply chain partners concerning the status of environmental sustainability efforts:

H2. Information sharing is positively associated with green information systems.

Dedrick (2010) defines green information systems as "the use of information systems to enhance sustainability across the economy." Watson *et al.* (2010) argue that green information systems initiatives can improve poor environmental practices that result in environmental wastes such as unused resources, energy inefficiencies, and emissions. Watson *et al.* (2010) propose the creation of a new subfield of information systems that is focused on the role that information systems can play in reducing energy consumption and greenhouse gas emissions. No empirical studies specifically relating green information systems and environmental performance where found during the literature search. Green *et al.* (2012) do offer related empirical evidence that the information system capabilities of environmental collaboration and monitoring among manufacturers and their supply chain partners positively impact environmental performance. Green information systems focus organizational and supply chain attention on environmental sustainability initiatives and outcomes. Progress toward environmental performance objectives cannot be monitored and corrective action is unlikely to be successfully undertaken without specific information provided through an established green information system. A lack of information, therefore, becomes a hindrance to achieving environmental outcomes and improving environmental performance:

H3. Green information systems are positively associated with environmental performance.

While the ability to share information among supply chain partners through established ERP systems is a necessary precursor to environmental performance, it is not sufficient alone to improve environmental performance. A green information system must necessarily be built on the ERP foundation before environmental performance can be fully leveraged. This claim of mediation is based primarily on the argument of Watson *et al.* (2010) that a new field of environmental informatics is needed to address the role of information systems in pursuing environmental sustainability. Watson *et al.* (2010) make it clear that information systems as they currently exist are insufficient to support sustainability efforts. Instead, existing information systems, such as ERP systems, must be expanded to incorporate green information systems capabilities. We argue that a significant portion of the impact of information sharing is explained by the degree to which an organization has developed and maintains a green information system:

H4. Green information systems mediate the relationship between information sharing and environmental performance.

3. Methodology

Data were collected from a sample of managers working for US manufacturing organizations via an on-line data service (Zoomerang through Market Tools, Inc.) during the spring of 2010. The survey instrument incorporates measurement scales for the three study constructs: information sharing, green information systems, and environmental performance.

The information sharing scale is taken from Green *et al.* (2007). The information sharing scale includes items designed to reflect managers' perceptions of the degree to which their organizations share information with customers and suppliers on a real-time synchronous basis. The green information systems scale is structured from items specified by Esty and Winston (2006). The green information systems scale includes items designed to reflect managers' perceptions of the degree to which an organization's information system is used to monitor energy use, environmental emissions, and the use of toxic and hazardous materials. The environmental performance scale is taken from Zhu *et al.* (2008). The environmental performance scale includes items designed to reflect managers' perceptions of their organization's performance related to reductions in energy use, environmental emissions, and use of toxic and hazardous materials. All study scales are displayed in Table I.

Because all of the measurement scales are from previous research, content validity is assumed. All measurement scales are further assessed for reliability and validity within a measurement model context as recommended by Koufteros (1999). Non-response bias and common method bias are assessed. Summary variables are computed and descriptive statistics and correlations computed. The descriptive statistics provide information necessary to determine whether the study variables are sufficiently normally distributed, and the correlations are used to establish relationships among pairings of the study variables. The hypotheses in the theorized model are assessed by evaluating the sign and significance of the standardized coefficients provided through the use of a covariance-based structural equation modeling methodology. Specifically, the software package used to complete the SEM analysis is LISREL 8.8.

4. Results

4.1 Survey effectiveness

2,325 managers were contacted via an e-mail methodology. Of the 2,325 contacted, 342 were screened out as non-managers and 255 managers completed the survey. Of the 255 respondents, 96 selected the "other manager" category. Because of concerns related to a lack of knowledge of green supply chain management practices and plant and organizational performance, data from the 96 were not included in the dataset analyzed. Finally, data from 159 manufacturing managers likely to have the necessary knowledge to fully complete the survey were included in the dataset that is subsequently analyzed. The effective response rate, therefore, is 6.8 percent.

Lambert and Harrington (1990) describe a common approach to assessment of non-response bias as comparing the first and second waves and assuming that "non-response bias is nonexistent if no differences exist on the survey variables." Following this common approach, respondents were categorized as responding to either the initial or follow-up requests sent approximately two weeks later. Those responding to the initial requests were classified as early responders; those responding to the follow-up requests were classified as late responders. 64 percent (101) of the

Table I.
Measurement scales

Information sharing (Green *et al.*, 2007) Please indicate the extent to which agree or disagree with each statement (1 – strongly disagree, 5 – strongly agree)	1. We are able to more quickly respond to customer needs by sharing information with our suppliers (IS1) 2. Information flows seamlessly between the suppliers, manufacturers and customers in our supply chain (IS2) 3. We openly share information with our suppliers and customers (IS3) 4. Our suppliers and customers openly share information with us (IS4) 5. The information shared by participants (suppliers, manufacturers and customers) in our supply chain is available on a real-time basis (IS5)
Green information systems (Esty and Winston, 2006) Please indicate the extent to which your organization's information system is used for each of the following (1 – not used at all; 5 – used to a great extent)	1. [a]Reducing transportation costs (GIS1) 2. [a]Supporting team work and meetings of globally distributed employees to limit their air travel (GIS2) 3. Tracking environmental information (such as toxicity, energy used, water used, air pollution) (GIS3) 4. Monitoring emissions and waste production (GIS4) 5. Providing information to encourage green choices by consumers (GIS5) 6. Improving decision making by executives by highlighting sustainability issues (GIS6) 7. [a]Reducing energy consumption (GIS7) 8. Supporting the generation and distribution of renewable energy (GIS8) 9. Limiting carbon and other emissions (GIS9) 10. Identifying the role of IS in energy policy (GIS10)
Environmental performance (Zhu *et al.*, 2008a) Please indicate the extent to which you perceive that your plant has achieved each of the following during the past year (1 – not at all; 2 – a little bit; 3 – to some degree; 4 – relatively significant; 5 – significant)	1. Reduction of air emissions (ENP1) 2. Reduction of effluent waste (ENP2) 3. Reduction of solid wastes (ENP3) 4. Decrease in consumption for hazardous/harmful/toxic materials (ENP4) 5. [a]Decrease in frequency for environmental accidents (ENP5) 6. [a]Improvement in an enterprise's environmental situation (ENP6)

Note: [a]Items removed to improve measurement model fit respondents were categorized as early respondents and 36 percent (58) were categorized as late respondents. A comparison of the means of the demographic variables and the summary variables for the two groups was conducted using one-way ANOVA. The comparisons resulted in statistically non-significant differences at the 0.01 level. 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 indicates that non-response bias has not negatively impacted the assembled dataset.

4.2 Sample description

All of the respondents hold plant-level management positions in manufacturing organizations. 22 percent of the respondents identified themselves specifically as plant managers, 32.7 percent as operations managers, 10.1 percent as engineering managers, 9.4 percent as information systems managers, 8.8 percent as sales managers, and 7.6 percent as purchasing managers. The remaining 9.4 percent hold logistics, supply chain, or industrial waste manager positions. Respondents average 11 years in their current positions. The mean number of employees per firm is 15,573, and the mean number of plant employees is 497. Respondents are from organizations that fall within 20 different North American Industry Classification System (NAICS) manufacturing categories. The sample is relatively diverse as intended and is made up of individuals with good knowledge of their plant's green supply chain management practices and plant and organizational performance. Table II provides a more detailed description of the sample.

4.3 Scale assessment process

Quality measurement scales must exhibit validity and reliability. Since all scales were taken directly from prior research (Zhu *et al.*, 2008; Green *et al.*, 2007; Esty and Winston, 2006), content validity is assumed. Gerbing and Anderson (1988) recommend that scales be tested for discriminant validity using a χ^2 difference test for each pair of scales under consideration. A statistically significant difference in χ^2 indicates discriminant validity (Garver and Mentzer, 1999; Ahire *et al.*, 1996; Gerbing and Anderson, 1988). The χ^2 difference tests for pairings of each scale with other study scales returned significant differences at the 0.01 level, indicating sufficient discriminant validity for all scales. Garver and Mentzer (1999) recommend reviewing the magnitude of the parameter estimates for the individual measurement items to assess convergent validity with statistical significance of an estimate indicating a weak condition of validity and an estimate greater than 0.70 indicating a strong condition. The standardized coefficients and associated *t*-values are displayed in Table III. All coefficients exceed the 0.70 minimum and are significant at the 0.01 level indicating sufficient convergent validity. Garver and Mentzer (1999) recommend computing Cronbach's coefficient α to assess scale reliability. They indicate that α values greater than or equal to 0.70 indicate sufficient reliability. All of the reliability coefficients exceed the recommended 0.70 level indicating sufficient reliability.

4.4 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 (Podsakoff and Organ, 1986). Lindell and Brandt (2000) recommend

	Number	Percentage (%)
Title		
Plant manager	35	22.0
Operations manager	52	32.7
Purchasing manager	12	7.6
Logistics manager	7	4.4
Sales manager	14	8.8
Engineering manager	16	10.1
Industrial waste manager	1	0.6
Supply chain manager	7	4.4
Information systems manager	15	9.4
Total number and percentage	159	100.0
NAICS industry category		
311 Food manufacturing	8	5.0
312 Beverage and tobacco product manufacturing	4	2.5
313 Textile mills	1	0.6
315 Apparel manufacturing	2	1.3
316 Leather and allied product manufacturing	1	0.6
321 Wood product manufacturing	9	5.7
322 Paper manufacturing	4	2.5
323 Printing and related support activities	9	5.7
324 Petroleum and coal products manufacturing	2	1.3
325 Chemical manufacturing	8	5.0
326 Plastics and rubber products manufacturing	13	8.2
327 Nonmetallic mineral product manufacturing	2	1.3
331 Primary metal manufacturing	10	6.3
332 Fabricated metal product manufacturing	25	15.7
333 Machinery manufacturing	8	5.0
334 Computer and electronic product manufacturing	6	3.8
335 Electrical equipment, appliance, and component manufacturing	6	3.8
336 Transportation equipment manufacturing	5	3.1
337 Furniture and related product manufacturing	1	0.6
339 Miscellaneous manufacturing	35	22.0
Total number and percentage	159	100.0
Mean years in current position	10.85	
Mean number of plant employees	497.37	
Mean number of firm employees	15,573.27	

Table II.
Sample demographics summary

using the smallest correlation among the variables measured by the survey instrument as a proxy for common method variation. First, it should be noted that a measurement scale for organizational performance was included in the survey instrument although not included in the theorized model (Figure 1). The smallest correlation among the variables measured in the survey is 0.337 between environmental performance and organizational performance. The smallest correlation among the hypothesized relationships is 0.526 for information sharing and environmental performance. Substituting these correlations into the formulas provided by Malhotra *et al.* (2007) results in a computed z-score is 3.70. This computed z-score corresponds with significance at the 0.01 level. Adjusting for common method variance using the smallest correlation (0.337) among all variables for which measurement scales were included in the survey, the smallest correlation among the hypothesized relationships (0.526) remains significantly

Table III.
Measurement model results

Construct/measures	α	Standardized coefficients	t-values
SC information sharing	0.906		
IS1		0.79	11.74
IS2		0.89	13.93
IS3		0.86	13.30
IS4		0.87	13.41
IS5		0.86	13.26
Green information systems	0.959		
GIS3		0.84	12.99
GIS4		0.84	12.97
GIS5		0.93	15.46
GIS6		0.92	15.26
GIS8		0.89	14.28
GIS9		0.95	16.09
GIS10		0.95	16.03
Environmental performance	0.915		
ENP1		0.88	13.95
ENP2		0.91	14.74
ENP3		0.90	14.49
ENP4		o.85	13.05

Notes: RMSEA = 0.108; NNFI = 0.964; CFI = 0.970; SRMR = 0.043

different from 0 at the 0.01 level. Based on this evidence, problems associated with common method bias are not considered significant (Podsakoff and Organ, 1986; Lindell and Whitney, 2001).

4.5 Measurement model assessment

As Koufteros (1999) recommends, the scales are assessed within the context of the full measurement model using a confirmatory factor analysis methodology. The results of this confirmatory factor analysis are displayed in Table III. Bagozzi and Yi (2012) identify root mean square error of approximation (RMSEA), non-normed fit index (NNFI), comparative fit index (CFI), and standardized root mean square residual (SRMR) as collectively providing a satisfactory criteria for the evaluation of overall model fit. Bagozzi and Yi (2012) recommend the following standards for model fit: RMSEA $\leq$ 0.07, NNFI $\geq$ 0.92, CFI $\geq$ 0.93, and SRMR $\leq$ 0.07. The measurement model fit is supported by the values of the following fit indices: NNFI = 0.96, CFI = 0.97 and SRMR = 0.04. The RMSEA value of 0.11 exceeds the recommended maximum, however. It should be noted that RMSEA values are upwardly biased for relatively small models as is the case here (Fan and Sivo, 2007). Based on these results, we argue that the model fit is sufficient to support testing of the study hypotheses.

4.6 Structural equation modeling results

Summary values for the study variables were computed by averaging the items in the scales. Descriptive statistics are presented in Table IV. All variables are normally distributed with skewness and kurtosis coefficients within the −2.00 and +2.00 range. The correlations are presented in Table IV. Correlation coefficients are positive and significant at the 0.01 level for all variable pairings.

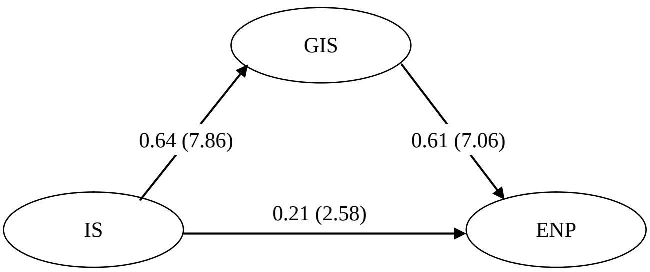
Figure 2 shows the results of the structural equation modeling analysis. *H1-H3* are supported with positive and significant standardized coefficients. Information sharing is positively associated with environmental performance with a coefficient of 0.21 and an associated *t*-value of 2.58. Information sharing is positively associated with green information systems with a coefficient of 0.64 and an associated *t*-value of 7.86. The green information systems construct is positively associated with environmental performance with a coefficient of 0.61 and an associated *t*-value of 7.06.

Determination of the mediating impact of green information systems (*H4*) requires computation of the indirect effect of information sharing on environmental performance through green information sharing. A variable serves as a mediator when it explains a significant portion of the relationship between an independent variable and a dependent variable (MacKinnon *et al.*, 1995). The mediation or indirect effect (0.39) is the product of standardized coefficients linking information sharing to green information systems (0.64) and green information systems to environmental performance (0.61). When the two path coefficients are significant at the 0.01 level as is the case here, the indirect effect is likely to also be significant at the 0.01 level (Kline, 2011, p. 165). To statistically test this assertion, Kline (2011, p. 165) recommends use of the Sobel test for significance of indirect effects. In this case, the Sobel test assesses the degree to which the mediator variable (green information systems) carries the influence of the independent variable (information sharing) through to the dependent variable (environmental performance). The Sobel test statistic is 5.26 with a two-tailed *p*-value of 1.5×10^{-7}, indicating that the indirect effect is significant at the 0.01 level. This finding supports green information systems as a partial mediator of the relationship between supply chain information sharing and environmental performance.

Variable	Minimum	Maximum	Mean	SD	Skewness	Kurtosis	IS	GIS
IS	1.00	5.00	3.7409	0.77216	−0.479	0.497		
GIS	1.00	5.00	3.2507	1.01454	−0.322	−0.597	0.564**	
ENP	1.00	5.00	3.4811	1.02828	−0.474	0.104	0.526**	0.700**

Notes: Correlation significant at: **0.01 level (two-tailed); IS – information sharing; GIS – green information systems; ENP – environmental performance

Table IV. Descriptive statistics and correlations



Notes: *RMSEA* = 0.108; *NNFI* = 0.964; *CFI* = 0.970; *SRMR* = 0.043; IS – information sharing, GIS – green information systems, ENP – environmental performance

Figure 2. Structural model results with standardized coefficients and (*t*-values)

4.7 Interpretation of the results

Information sharing and green information systems combine to positively impact environmental performance. The direct impact of information sharing on environmental performance is partially but significantly mediated by green information systems. Before introducing green information systems into the model, the standardized coefficient for the information sharing to environmental performance link is 0.64. The introduction of green information systems as a mediator reduces the coefficient from 0.64 to 0.21. Because the coefficient of 0.21 remains significant, the green information systems construct serves as a partial mediator. It should be noted, however, that the indirect effect (0.39) is stronger than the direct effect (0.21). These results are believed to be the first to empirically establish the important role that information systems play in the achievement of environmental sustainability.

5. Conclusions

Manufacturing organizations with functioning ERP systems generally have the ability to share information with supply chain partners. The existence of an ERP system and the ability to share information establish a technological environment suitable for the development of a green information system. The results indicate that this ability to synchronously share real-time information with suppliers and customers is a necessary precursor to the effective installation of a green information system. Once the ERP system has been modified to monitor the environmental sustainability initiatives and outcomes of the supply chain partners, the supply chain partners can make collaborative decisions leading to improved environmental performance. Manufacturing organizations without the ability to share information and monitor environmental programs and outcomes are unlikely to see improvements in environmental performance.

5.1 Limitations of the study

While we believe that the objectives of the study are met, there are some limitations of the study that should be considered. The data collection survey focused on manufacturing managers working within the US manufacturing sector with a relatively diverse group of managers providing the data. Such survey research raises concerns related to non-response bias and common method bias. In addition, it should be noted that the measurement scales required that respondents provide their opinions related to the degree to which green supply chain management practices are used within their manufacturing plants and organizations. Although precautions were taken to ensure that knowledgeable managers completed the surveys and tests for the biases were conducted without negative results, these limitations should be considered when interpreting the study results.

There is concern related to the appropriateness of using covariance-based SEM to conduct the structural analysis and hypotheses tests. Consideration should also have been given to the use of OLS regression and PLS-SEM as alternative methods of structural analysis. In particular PLS-SEM is better suited for small samples when prediction is emphasized over theory testing (Hair *et al.*, 2011). In this case the sample is relatively small and the degree to which information sharing and green information systems predict environmental performance is of prime importance as opposed to true theory testing. To alleviate concerns related to statistical methodology, a post-study comparison of the results of the three alternatives (OLS regression, CB-SEM, and PLS-SEM) indicates no significant differences in findings. Thus, conclusions and implications are the same for all statistical analysis alternatives.

5.2 Future research

This is the first empirical assessment of the theorized model. It is important that the model be assessed using data from additional samples to support generalization of the results. In addition, this research focuses on the implementation of certain practices related to environmental sustainability by manufacturing organizations. The model was constructed to assess the impact of information sharing and green information systems on environmental performance from the perspective of manufacturers as they operate within a supply chain context. Further research based on supplier and customer samples is warranted.

Melville (2010) and Watson *et al.* (2010) argue that the role of information systems in environmental sustainability is not well established and this deficiency should be addressed through further theoretical development and empirical assessment. The study is one of the first to report empirical results relating information systems and environmental sustainability. The model investigated is somewhat simplistic, however. Additional independent and dependent variables should be incorporated in future research. For example, other green supply chain management practices such as green purchasing, cooperation with customers, eco-design, and environmental monitoring could be incorporated along with information sharing. It is logical that information sharing supports green practices that require communication and collaboration among supply chain partners.

5.3 Implications for practitioners

The results provide manufacturing managers with valuable information related to the technological environment in which the implementation of green supply chain management practices are most successful. Improved environmental performance from green information systems depends on the existence of an established ERP system that enables synchronous sharing or real-time information with suppliers and customers. If this ability to share information is not present, the full impact of green supply chain management practices on environmental performance is not likely to be realized. If the information sharing capabilities are in place, manufacturers can proceed to build green information monitoring features into the ERP system followed by establishing environmental sustainability linkages with suppliers and customers. To summarize, based on the results of this study, we recommend the implementation of green information systems only when an established ERP system is available to support information sharing with suppliers and customers.

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About the authors

Jeramy Meacham has a PhD from Jackson State University and is an Assistant Professor of Management at Southern Arkansas University. His research has appears in the *Journal of Information and Knowledge Management*, *Industrial Management & Data Systems*, and *Supply Chain Management: An International Journal*.

Lisa Toms has a DBA from Louisiana Tech University and is the Dean of the College of Business at Southern Arkansas. Her research appears in *Journal of Applied Business Research*, *Ethics and Critical Thinking Journal*, *Journal of Business Administration Online*, *M-PBEA Journal*, and *Ethics and Critical Thinking Journal*.

Kenneth W. Green Jr has a DBA from Louisiana Tech University and the LeMay Professor of Technology at Southern Arkansas University. His research appears in *Journal of Operations Management*, *International Journal of Operations & Production Management*, *International Journal of Production Research*, *Industrial Marketing Management*, *International Journal of Human Resource Management*, *Supply Chain Management: An International Journal*, *Production Planning and Control*, *Industrial Management & Data Systems*, *Journal of Computer Information Systems*, and *Management Research Review*. Kenneth W. Green Jr is the corresponding author and can be contacted at: kwgreen@saumag.edu

Vikram S. Bhadauria is a PhD from University of Texas at Arlington and is an Assistant Professor of Management Information Systems at Southern Arkansas University. His research appears in *Industrial Management & Data Systems* and *Supply Chain Management: An International Journal*.