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Emerald Article: Green supply chain management practices: impact on performance

Kenneth W. Green Jr, Pamela J. Zelbst, Jeramy Meacham, Vikram S. Bhadauria

Green supply chain management practices: impact on performance

Kenneth W. Green Jr
Department of Management, Marketing, and Management Information Systems, Southern Arkansas University, Magnolia, Arkansas, USA

Pamela J. Zelbst
Department of Management and Marketing, Sam Houston State University, Huntsville, Texas, USA, and

Jeramy Meacham and Vikram S. Bhadauria
Department of Management, Marketing, and Management Information Systems, Southern Arkansas University, Magnolia, Arkansas, USA

Abstract

Purpose – The aim is to contribute significantly to the first wave of empirical investigations related to the impact of green supply chain management (GSCM) practices on performance. The paper also aims to theorize and empirically assess a comprehensive GSCM practices and performance model. The model incorporates green supply chain practices that link manufacturers with supply chain partners (both suppliers and customers) to support environmental sustainability throughout the supply chain.

Design/methodology/approach – Data collected from 159 manufacturing managers were analyzed using a structural equation modeling methodology. Manufacturing managers provide data reflecting the degree to which their organizations work with suppliers and customers to improve environmental sustainability of the supply chain.

Findings – Generally, the adoption of GSCM practices by manufacturing organizations leads to improved environmental performance and economic performance, which, in turn, positively impact operational performance. Operational performance enhances organizational performance.

Research limitations/implications – As a first wave empirical investigation of the impact of GSCM practices on performance, the study is by necessity exploratory.

Practical implications – Practitioners are provided with a framework for assessing the synergistic impact of GSCM practices on performance. Internal environmental management and green information systems are identified as necessary precursors to the implementation of green purchasing, cooperation with customers, eco-design, and investment recovery.

Originality/value – A comprehensive GSCM practices performance model is proposed and empirically assessed. The results of this investigation support the proposition that GSCM practices are both environmentally necessary and good business. A structured two-wave approach to the implementation of GSCM practices is recommended.

Keywords Green supply chain management, Green information systems, Environmental performance, Economic performance, Operational performance, Organizational performance

Paper type Research paper

1. Introduction

Supply chain management (SCM) requires the integration and coordination of business processes and strategy alignment throughout the supply chain for the purpose of satisfying the final customers of the supply chain (Green *et al.*, 2008, 2006; Cohen and Roussel, 2005; Ho *et al.*, 2002). Business processes that must be integrated and coordinated include purchasing, manufacturing, marketing, logistics, and information systems. Strategic imperatives that must be aligned include customer focus, efficiency, quality, and responsiveness (Zelbst *et al.*, 2010), and most recently environmental sustainability. With competition at the supply chain level and a focus on the changing demands of final customers, it is necessary to identify and adopt practices that yield competitive advantage at the supply chain level which, in turn, yield improved performance for the individual supply chain partners (Green *et al.*, 2008). Environmental sustainability is a supply chain imperative rather than an organizational imperative (Vachon and Klassen, 2007; Vachon and Klassen, 2006; Vasileiou and Morris, 2006). Development of environmentally friendly processes, products, and services requires a unified effort by all members of the supply chain to avoid sub-optimization at the partner level (Vasileiou and Morris, 2006).

Manufacturing organizations have begun to implement green supply chain management (GSCM) practices in response to customer demand for products and services that

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are environmentally sustainable and that are created through environmentally sustainable practices and in response to governmental environmental regulations (Murray, 2000; Green *et al.*, 1998). These practices require that manufacturers work in concert with suppliers and customers to enhance environmental sustainability. The implementation of GSCM practices is expected to result in improved environmental performance as measured by reductions in air emissions, effluent waste, solid waste, and the consumption of toxic materials. There is concern, however, whether such environmental sustainability efforts will ultimately translate into improved market share and profitability. Ultimately, manufacturing managers are responsible for the performance of the organizations for which they work (Green *et al.*, 2008). How best can they improve organizational performance within the context of their supply chains? Local managers must make decisions that support the supply chain first and their organizations second (Green *et al.*, 2008). In short, managers must "globalize to localize." Success at the supply chain level leads to success at the organizational level (Chopra and Meindl, 2004). Since customers and governmental entities have begun to demand that processes, products, and services be environmentally friendly, it is important that managers identify and implement environmental sustainability practices that extend throughout the supply chain.

Klassen (1993) and Preuss (2002) argue for integrating environmental issues into the mainstream of SCM. Handfield *et al.* (1997) suggest that environmental sustainability efforts be integrated throughout the value chain. Linton *et al.* (2007) assert that the focus of environmental management has moved from the organization level to the supply chain level. Whether going "green" really pays has been investigated with inconclusive results (King and Lenox, 2001; Rao and Holt, 2005; Zhu and Sarkis, 2004). Seuring (2004) questions whether the adoption of environmental sustainability results in a win-win situation or environmental and economic tradeoffs for the supply chain partners. There is a lack of empirical research that looks into this phenomenon from a holistic and integrated perspective that could be used as a foundation for both theory building and theory testing.

We contribute to the GSCM literature by incorporating recently developed constructs (Zhu *et al.*, 2008a; Green and Inman, 2005; Esty and Winston, 2006) in a comprehensive GSCM practices model and providing early empirical evidence concerning the efficacy of the model. Generally, we propose that manufacturing organizations should adopt environmental sustainability as a strategic imperative and expand existing enterprise information system capabilities to monitor environmental sustainability activities and outcomes prior to implementation of GSCM practices. Further, we propose that successful implementation of GSCM practices such as green purchasing, cooperation with customers, eco-design, and investment recovery will lead to improved environmental and economic performance which support improved operational and organizational performance. A theorized model is assessed using data from a national sample of 159 managers working for US manufacturing organizations. The managers responded to survey items related to the internal environmental practices of their organizations and to the environmental practices coordinated and integrated with both suppliers and customers.

2. Literature review and hypotheses development

The broad view of sustainability incorporates the concepts of economic, social, and environmental performance (Carter and Easton, 2011; Carter and Rogers, 2008). The literature related to sustainability is relatively well developed (Carter and Easton, 2011; Carter and Rogers, 2008). Our focus is on the environmental performance component of sustainability. The focus of environmental management has moved from the organization level to the supply chain level (Linton *et al.*, 2007; Preuss, 2002). Seuring (2004) describes "environmental supply chain management" as the managerial integration of material and information flows throughout the supply chain to satisfy the demand of customers for green products and services produced by green processes.

Supply chains strive to maintain internal health and environmental sustainability using the capability to self correct based on information from the external environment (Vachon, 2007). As the organizations making up a supply chain become aware of customer demands for products and services provided without damage to the environment, managers will make decisions that support the integration and coordination of GSCM practices throughout the supply chain (Vachon and Klassen, 2007; Vachon and Klassen, 2006). Supply chains and organizations can gain competitive advantage by being the first to adopt environmental sustainability and implement GSCM practices (Sen, 2009; Barratt and Oke, 2007; Handfield *et al.*, 1997). Preuss (2001, 2002) emphasizes the "boundary-spanning" role of SCM as key to the implementation of environmental strategies both downstream and upstream through the supply chain. He describes the possibility of a "green multiplier effect" resulting from the collaboration of supply chain partners concerning environmental issues. Seuring (2001) cautions that transaction costs associated with interactions among supply chain partners must be considered as the partners work to improve the environmental sustainability of the supply chain.

In addition to customer requirements, environmental legislation and regulation have been identified as drivers of the adoption of green practices (Preuss, 2002). There is not a clear consensus of the impact of environmental legislation on firm competitiveness. Jorgensen and Wilcoxen (1990) quantify the impact of the costs of pollution controls on costs of goods and services in the US economy. While they estimate that pollution abatement may account for as much as 10 percent of the total costs of some goods and services, they do not assess the benefits associated with a cleaner environment. There is concern that firms may lose competitive advantage due to the increased costs from implementation of environmental sustainability guidelines. Jaffe *et al.* (1995) conclude that there is little evidence to support the proposition that environmental regulations damage competitiveness. More empirical research is necessary to definitively establish the impact of environmental sustainability legislation on the competitiveness of business firms.

The literature specifically related to GSCM is in the early stages of development, with related articles dealing primarily with theoretical discussions and anecdotal evidence (Quazi, 2001). In addition, a number of authors have done preliminary work in developing measurement scales related to environmental sustainability (Zhu *et al.*, 2008a; Vachon and Klassen, 2006; Wee and Quazi, 2005). King and Lenox (2001) raise the question of whether or not embracing environmental sustainability really pays. They do not find a strong and conclusive link between environmental sustainability practices and environmental and financial performance and call for further empirical investigation. The existing research provides some direction but remains inconclusive (Rao and Holt, 2005; Zhu and Sarkis, 2004).

2.1 Theoretical model

Each of the hypotheses depicted in Figure 1 is theorized as being direct and positive. Definitions of the constructs incorporated in the model are provided in Table I. Generally, GSCM practices are the focal constructs in the theorized model with internal environmental management and green information systems as antecedents and environmental, economic, operational, and organizational performance as consequences. In addition, green information systems provide the information necessary to make decisions about green purchasing, the level of cooperation with customers, design of the product, and investment recovery. Changes made as a result of internal environmental management or green information systems impact the ability to implement green supply chain practices which will impact environmental performance, economic performance, operational performance, and organizational performance.

2.2 Hypotheses

2.2.1 Internal environmental management and green information systems

Once firms adopt environmental sustainability as a strategic imperative, they can proceed to develop green information systems capabilities. Information systems are essential for creation, maintenance, and survival of supply chains. Adoption of environmental sustainability as a strategic imperative requires that organizations develop and implement green information systems. A strategic focus on GSCM 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). Information systems are primarily used by organizations for providing tools, techniques, and mechanisms for collaboration. Jiang and Klein (1999) found that management support was a necessary precursor to successful information system implementation:

H1. Internal environmental management directly and positively impacts green information systems.

2.2.2 Internal environmental management and green supply chain practices

Once environmental sustainability has been adopted as a strategic imperative and the imperative receives the commitment and support from top and mid-level management, the organization can proceed with the implementation of the GSCM practices of green purchasing, cooperation with customers, eco-design, and investment recovery. The incorporation of the imperative into the overall strategy of the organization is a necessary precursor to successful implementation of the practices (Murray, 2000). Top-management support is a key driver of the successful adoption and implementation of innovations, including new technologies, programs, and activities (Hamel and Prahalad, 1989). To ensure environmental excellence, top management must be totally committed (Rice, 2003; Zsidisin and Siferd,

Figure 1 Comprehensive green supply chain management practices performance model with hypotheses

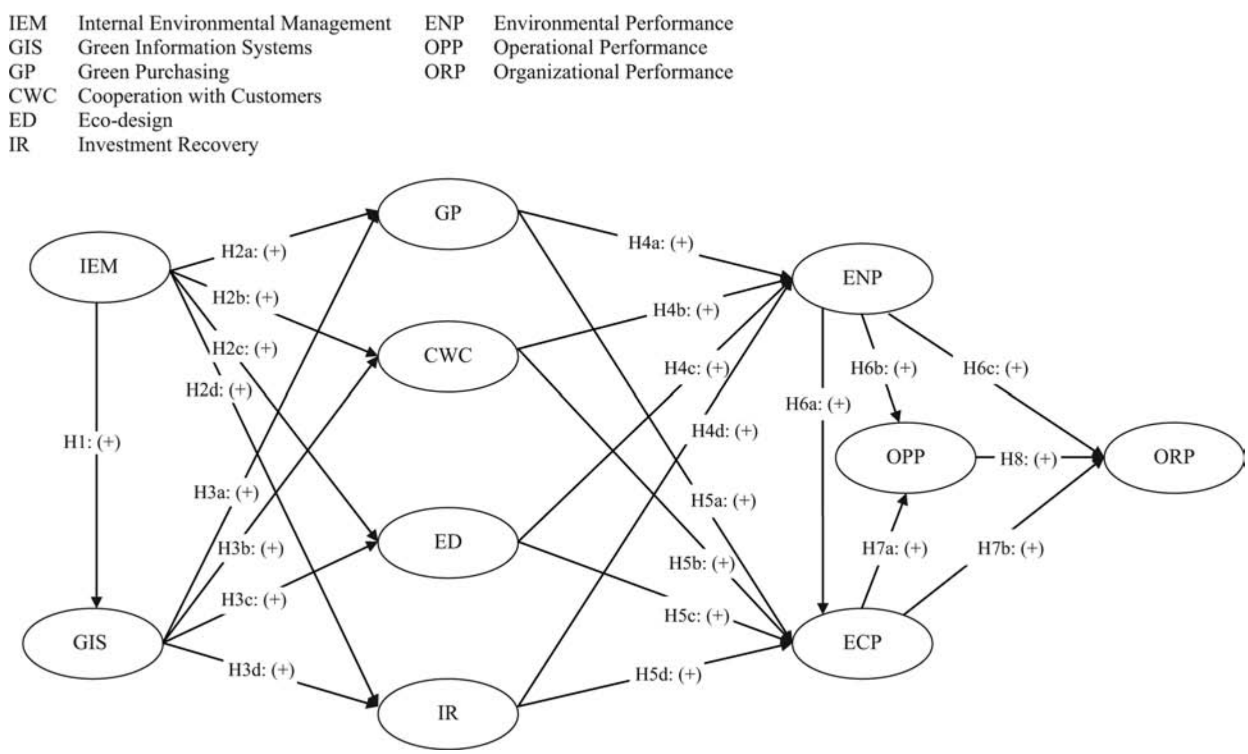


Table I Construct definitions

Construct	Definition
Internal environmental management	Internal environmental management is the practice of developing green supply chain management as a strategic organizational imperative through commitment and support of the imperative from senior and mid-level managers (Zhu *et al.*, 2008a)
Green information systems	Green information systems are information systems that have been modified and are used to monitor environmental practices and outcomes (Esty and Winston, 2006)
Green purchasing	Green purchasing focuses on cooperating with suppliers for the purpose of developing products that are environmentally sustainable (Zhu *et al.*, 2008a; Carter and Carter, 1998)
Cooperation with customers	Cooperation with customers requires working with customers to design cleaner production processes that produce environmentally sustainable products with green packaging (Zhu *et al.*, 2008a)
Eco-design	Eco-design requires that manufacturers design products that minimize consumption of materials and energy, that facilitate the reuse, recycle, and recovery of component materials and parts, and that avoid or reduce the use of hazardous products within the manufacturing process (Zhu *et al.*, 2008a)
Investment recovery	Investment recovery requires the sale of excess inventories, scrap and used materials, and excess capital equipment (Zhu *et al.*, 2008a)
Environmental performance	Environmental performance relates the ability of manufacturing plants to reduce air emissions, effluent waste, and solid wastes and the ability to decrease consumption of hazardous and toxic materials (Zhu *et al.*, 2008a)
Economic performance	Economic performance relates to the manufacturing plant's ability to reduce costs associated with purchased materials, energy consumption, waste treatment, waste discharge, and fines for environmental accidents (Zhu *et al.*, 2008a).
Operational performance	Operational performance relates to the manufacturing plant's capabilities to more efficiently produce and deliver products to customers (Zhu *et al.*, 2008a)
Organizational performance	Financial and marketing performance of the organization as compared to the industry average (Green and Inman, 2005)

2001; de Bakker *et al.*, 2002). Zhu *et al.* (2008b) found that organizational learning and management support positively affect the implementation of GSCM practices. According to Klassen and McLaughlin (1993), environmental excellence starts during the initial product and process design. Management commitment to an environmental sustainability strategy is necessary to ensure that a full green life-cycle approach is adopted (Byrne and Deeb, 1993; Herod, 1989; Klassen and McLaughlin, 1993; Zsidisin and Hendrick, 1998):

H2a. Internal environmental management directly and positively impacts green purchasing.
H2b. Internal environmental management directly and positively impacts cooperation with customers.
H2c. Internal environmental management directly and positively impacts eco-design.
H2d. Internal environmental management directly and positively impacts investment recovery.

2.2.3 Green information systems and green supply chain management practices

The successful implementation of the GSCM practices 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). The data can then be analyzed to generate the information necessary to make decisions that lead to improved environmental sustainability throughout the supply chain (Preuss, 2002). In effect, 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, and transportation. Information sharing, through the use of green information systems, is a key enabler for SCM in terms of integration and coordination (Chandra *et al.*, 2007). Frohlich and Westbrook (2001) proposed 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 will provide the information necessary to make decisions about eco-design, in terms of material and energy consumption, reuse, recycling and recovery of materials. Green information systems also provide the information necessary to recover the organization's investment in excess inventories, scrap, and excess capital equipment:

H3a. Green information systems directly and positively impacts green purchasing.
H3b. Green information systems directly and positively impacts cooperation with customers.
H3c. Green information systems directly and positively impacts eco-design.
H3d. Green information systems directly and positively impacts investment recovery.

2.2.4 Green supply chain management practices and environmental performance

We argue that GSCM is now a strategic imperative based on customer demands for products that are environmentally sustainable themselves and that have been produced by processes that are designed and operated to enhance environmentally sustainability. Based on an analysis the Xerox, Ltd. product life cycle, McIntyre *et al.* (1998) propose evaluating the environmental performance outcomes of the various stages of the product life cycle using an environmental performance matrix that assesses the collective impact of environmental practices throughout the supply chain. Zhu and Sarkis (2004) found a positive relationship between adoption of green supply chain practices and improvements in environmental and economic performance. Geffen and Rothenberg (2000) found that, in the manufacturing setting, strong relationships and close collaboration with the suppliers results in improved environmental performance. Preuss (2001) describes the possibility of a "green multiplier effect" that results from the extension of green purchasing practices from immediate suppliers to second and third tier suppliers' suppliers. Based on anecdotal evidence, Green *et al.* (1998) argue that green purchasing and supply policies are likely to result in improved environmental performance. GSCM practices are developed specifically to improve the environmental performance of manufacturing firms. Practices, such as green purchasing, cooperation with customers, eco-design, and investment recovery, are designed to positively impact environmental performance. Diabat and Govindan (2011) studied various drivers that affect the implementation of green supply chains and found that green design positively influences the performance of green supply chains. The aim of eco-design is the reduction of a product's environmental impact without creating a negative trade-off with other design criteria, such as costs and functionality. Eco-friendly design and an emphasis on investment recovery will directly and positively influence environmental performance as the impetus of the designers will be on reducing the environmental impact of the design:

H4a. Green purchasing directly and positively impacts environmental performance.
H4b. Cooperation with customers directly and positively impacts environmental performance.
H4c. Eco-design directly and positively impacts environmental performance.
H4d. Investment recovery directly and positively impacts environmental performance.

2.2.5 Green supply chain management practices and economic performance

GSCM practices focus on the elimination of wastes associated with environmental sustainability. Such waste minimization should lead to reduced costs resulting in improved economic performance. Rao and Holt (2005) demonstrated a link between green supply chains and economic performance. They also found that GSCM practices led to competitiveness and better economic performance. Klassen and McLaughlin (1996) studied the effect of announcements of winning environmental awards by the organizations on stock prices. They found evidence that the market valued such recognition and duly awarded the firms with increased valuations as reflected by higher stock prices. We argue that GSCM practices enhance economic performance:

H5a. Green purchasing directly and positively impacts economic performance.
H5b. Cooperation with customers directly and positively impacts economic performance.
H5c. Eco-design directly and positively impacts economic performance.
H5d. Investment recovery directly and positively impacts economic performance.

2.2.6 Environmental, economic, operational, and organizational performance

The cost saving nature of environmental performance should lead to improved economic performance and both environmental performance and economic performance should yield improve operational efficiency. Environmental, economic, and operational performance generate cost savings and reflect an organization's ability to satisfy changing customer demands for environmentally sustainable products and services. The cost and marketing implications of environmental, economic, and operational performance should lead to improvement in the overall financial and marketing performance of the organization:

H6a. Environmental performance directly and positively impacts economic performance.
H6b. Environmental performance directly and positively impacts operational performance.
H6c. Environmental performance directly and positively impacts organizational performance.
H7a. Economic performance directly and positively impacts operational performance.
H7b. Economic performance directly and positively impacts organizational performance.
H8. Operational performance directly and positively impacts organizational performance.

3. Methodology

The GSCM practices performance model is theorized and the constructs included in the model are defined and described with a focus on manufacturing organizations. Considering this manufacturing focus, data were collected from a sample of plant-level managers working for US manufacturing organizations. It should be noted that the GSCM practices and environmental performance scales were originally assessed for validity using a sample of Chinese manufacturers (Zhu *et al.*, 2008a). Zhu *et al.* (2008a) recommend that validation of measurement scales be fully established through a series of studies testing the scales across industries and countries. The US sample provides an important contrast to the Chinese sample supporting validation and generalization. While we appreciate the importance of considering the environmental impact of processes and products as they extend fully through first-order and second-order supply chains as emphasized by Svensson (2007) and Preuss (2001), we necessarily adopt a more limited view of the supply chain incorporating manufacturing firms, immediate suppliers, and immediate customers for practical reasons. The available GSCM practices measurement scales support surveying manufacturers concerning environmental relationships with immediate suppliers and customers. The data were collected during the spring of 2010 via an on-line data service (Zoomerang through MarketTools, Inc.) following a data collection process similar to the one employed by Inman *et al.* (2009). This data collection process was managed by Zoomerang and was structured to ensure unique responses from validated members of the manufacturing panel. Two waves of requests to participate in the study were sent to 2,325 members of the panel. Screening questions were in place to identify only plant-level manufacturing managers working for US manufacturing organizations.

A total of 2,325 managers were contacted via an e-mail process, 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 GSCM practices and plant and organizational performance, data from the 96 were not included in the dataset analyzed. Data from 159 manufacturing managers likely to have the necessary knowledge to fully complete the survey were included in the dataset subsequently analyzed. The effective response rate is 8 percent (159/(2325-342)).

All of the respondents hold plant-level management positions in manufacturing organizations. The majority (55 percent) are plant and operations managers. The respondents selected 20 different industry categories representing a diverse array of manufacturing organizations. The respondents are experienced having been in their current positions an average of 10.85 years. They work for plants that have an average of 497 employees and firms with an average of 15,573 employees. The sample is diverse as intended and is made up of individuals with knowledge of their plant's GSCM practices and plant and organizational performance. Table II displays the sample demographics.

Respondents were categorized as responding to either the initial or follow-up requests that were sent approximately two weeks later. Of the respondents, 64 percent (101) 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; Lambert and Harrington, 1990), this finding of general equality between early and late respondents indicates that non-response bias has not negatively impacted the assembled data set.

The internal environmental management, green purchasing, cooperation with customers, eco-design, investment recovery, environmental performance, economic performance, and operational performance scales were developed and assessed by Zhu *et al.* (2008a). The organizational performance scale was previously used and assessed by Green and Inman (2005). The green information systems scale was developed from items identified by Esty and Winston (2006). The scales are displayed in the Appendix.

Since all scales were taken directly from prior research (Zhu *et al.*, 2008a; Green and Inman, 2005; Esty and Winston, 2006), content validity is assumed. Chi-square 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; Ahire *et al.*, 1996; Gerbing and Anderson, 1988). The standardized coefficients for scale items presented in Table III exceed the recommended 0.70 minimum and are significant at the 0.01 level indicating sufficient convergent validity (Garver and Mentzer, 1999). Cronbach alpha values for all of the measurement scales exceed the recommended 0.70 level indicating sufficient reliability (Garver and Mentzer, 1999). The scales are also assessed within the context of the full measurement model using confirmatory factor analysis (Koufteros, 1999). The results of this confirmatory factor analysis are displayed in Table III. The measurement model fits the data well with a relative chi-square value of 1.507, an RMSEA value of 0.057, a CFI value of 0.990, and an NNFI value of 0.988.

Table II Sample demographics summary

	Number
Title	
Plant manager	35
Operations manager	52
Purchasing manager	12
Logistics manager	7
Sales manager	14
Engineering manager	16
Industrial waste manager	1
Supply chain manager	7
Information systems manager	15
Total	159
Industry category	
Food manufacturing	8
Beverage and tobacco product manufacturing	4
Textile mills	1
Apparel manufacturing	2
Leather and allied product manufacturing	1
Wood product manufacturing	9
Paper manufacturing	4
Printing and related support activities	9
Petroleum and coal products manufacturing	2
Chemical manufacturing	8
Plastics and rubber products manufacturing	13
Nonmetallic mineral product manufacturing	2
Primary metal manufacturing	10
Fabricated metal product manufacturing	25
Machinery manufacturing	8
Computer and electronic product manufacturing	6
Electrical equipment, appliance, and component manufacturing	6
Transportation equipment manufacturing	5
Furniture and related product manufacturing	1
Miscellaneous manufacturing	35
Total	159
Mean years in current position	10.85
Mean number of plant employees	497.37
Mean number of firm employees	15,573.27

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 among the study variables is 0.316 between environmental performance and organizational performance. The smallest correlation among the relationships specified in the structural model is 0.512 for eco-design and economic performance. Substituting these correlations into the formulas provided by Malhotra *et al.*

Table III Measurement model results

Construct/measures	Alpha	Standardized coefficients	*t*-values
Internal environmental management	0.947		
IEM1		0.92	15.02
IEM2		0.92	14.89
IEM3		0.86	13.44
IEM4		0.86	13.36
Green information systems	0.956		
GIS5		0.88	14.08
GIS6		0.88	14.02
GIS8		0.85	13.20
GIS9		0.91	14.70
GIS10		0.91	14.68
Green purchasing	0.953		
GP1		0.85	13.32
GP2		0.88	13.91
GP3		0.88	14.07
GP5		0.89	14.38
GP6		0.91	14.87
Cooperation with customers	0.956		
CWC1		0.90	14.43
CWC2		0.90	14.43
CWC3		0.92	15.18
CWC4		0.89	14.28
Eco-design	0.903		
ED1		0.81	12.11
ED2		0.93	15.00
ED3		0.97	13.44
Investment recovery	0.816		
IR1		0.78	11.10
IR2		0.79	11.29
IR3		0.80	11.53
Environmental performance	0.920		
ENP1		0.83	12.62
ENP3		0.83	12.74
ENP4		0.85	13.09
ENP6		0.91	14.69
Economic performance	0.904		
ECP3		0.87	13.57
ECP4		0.92	14.87
ECP5		0.81	12.04
Operational performance	0.895		
OPP4		0.77	11.20
OPP5		0.92	14.84
OPP6		0.89	13.95
Organizational performance	0.938		
ORP2		0.90	14.30
ORP3		0.93	15.19
ORP4		0.88	13.88
ORP7		0.82	12.52

Notes: Chi-square ratio = 1.507; RMSEA = 0.057; NFI = 0.971; NNFI = 0.988; CFI = 0.990; IFI = 0.990

(2007) the computed z-score is 3.69. This computed z-score corresponds with significance at the 0.01 level. Adjusting for common method variance using the smallest correlation (0.316), the smallest correlation among the hypothesized relationships (0.512) remains significantly different from zero at the 0.01 level. Based on the results of the proxy test, problems associated with common method bias are not considered significant (Lindell and Whitney, 2001).

Summary variables, descriptive statistics, and correlation coefficients are computed. The theorized model is assessed following a structural equation modeling methodology. 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, because of the number of constructs embedded in the theoretical model, it was necessary to reduce the total number of measurement items by removing those items with standardized coefficients less than 0.75 from the measurement model. The traditional path analysis methodology based on regression analysis described by Kline (1998) is also considered as an appropriate model testing methodology.

Because of our objective to assess the theorized model as a whole, in spite of the small sample size and the large number of constructs, we opted to assess the model using structural equation modeling techniques. LISREL 17.0 software was used do perform both the confirmatory factor analysis necessary to assess the measurement model and the structural analysis necessary to assess the structural model because of the important model fit information available.

4. Results

4.1 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 sufficiently normally distributed with skewness and kurtosis coefficients within the −2.00 and +2.00 range. The correlations are presented in Table V. Correlation coefficients are positive and significant at the 0.01 level for all variable pairings.

Figure 2 illustrates the model with the structural equation modeling results specified in the LISREL 8.7 output. Results relating to fit of the model generally support a claim of good fit. The relative chi-square (chi-square/degrees of freedom) value of 1.67 is less than the 3.00 maximum recommended by Kline (1998) and the root mean square error of approximation (0.07) is below the recommended maximum of 0.08 (Schumacker and Lomax, 2004). While the GFI (0.73) is below the 0.90 level recommended by Byrne (1998), it is more heavily impacted by a small sample size and, as Byrne (1998) points out, the Comparative-Fit Index (CFI) and Incremental-Fit Index (IFI) are more appropriate when the sample size is small. The CFI (0.99) and IFI (0.99) both exceed the recommended 0.90 level (Byrne, 1998).

Hypotheses test results are presented in Table VI. *H1* through *H3d* are positive and significant as expected indicating that internal environmental management and green information systems are necessary precursors to implementation of GSCM practices. *H4a* through *H4d*, which predict positive associations between the GSCM practices and environmental performance, are positive and significant as expected with the exception of the green purchasing to environmental performance link. *H5a* through *H5d*, which predict positive associations between the GSCM practices and economic performance, are not positive and significant with the exception of the green purchasing to economic performance link. Cooperation with customers and investment recovery do not impact economic performance, while eco-design negatively impacts economic performance. *H6a*, *H7a* and *H6b* are positive and significant as expected indicating that environmental and economic performance positively impact operational performance. Of *H6c*, *H7b*, and *H8*, only the hypothesized positive link between operational performance and organizational performance (*H8*) is supported. Environmental and economic performance do not directly impact organizational performance, rather they indirectly impact organizational performance through operational performance.

4.2 Interpretation of results

Internal environmental management is positively associated with green information systems and both appear as antecedents to successful implementation of green purchasing, cooperation with customers, eco-design, and investment recovery. Manufacturing organizations first adopt environmental sustainability as a strategic imperative before modifying existing information systems to capture data and generate information related to environmental sustainability initiatives and outcomes. The first stage in implementing GSCM practices is to embrace the strategy organizationally and to modify existing enterprise resource planning (ERP) information systems to monitor environmental initiatives. The second stage includes implementation of green purchasing, cooperation with customers, eco-design, and investment recovery practices. The associations between the stage one and stage two practices are all positive and significant supporting the proposition that the practices should be implemented in stages.

The results linking the stage two GSCM practices to environmental and economic performance are not as clear cut. Environmental performance is focused on decreases in the levels of environmental pollutants, while economic performance is focused on reductions in environmentally related costs such as materials purchases and energy

Table IV Descriptive statistics

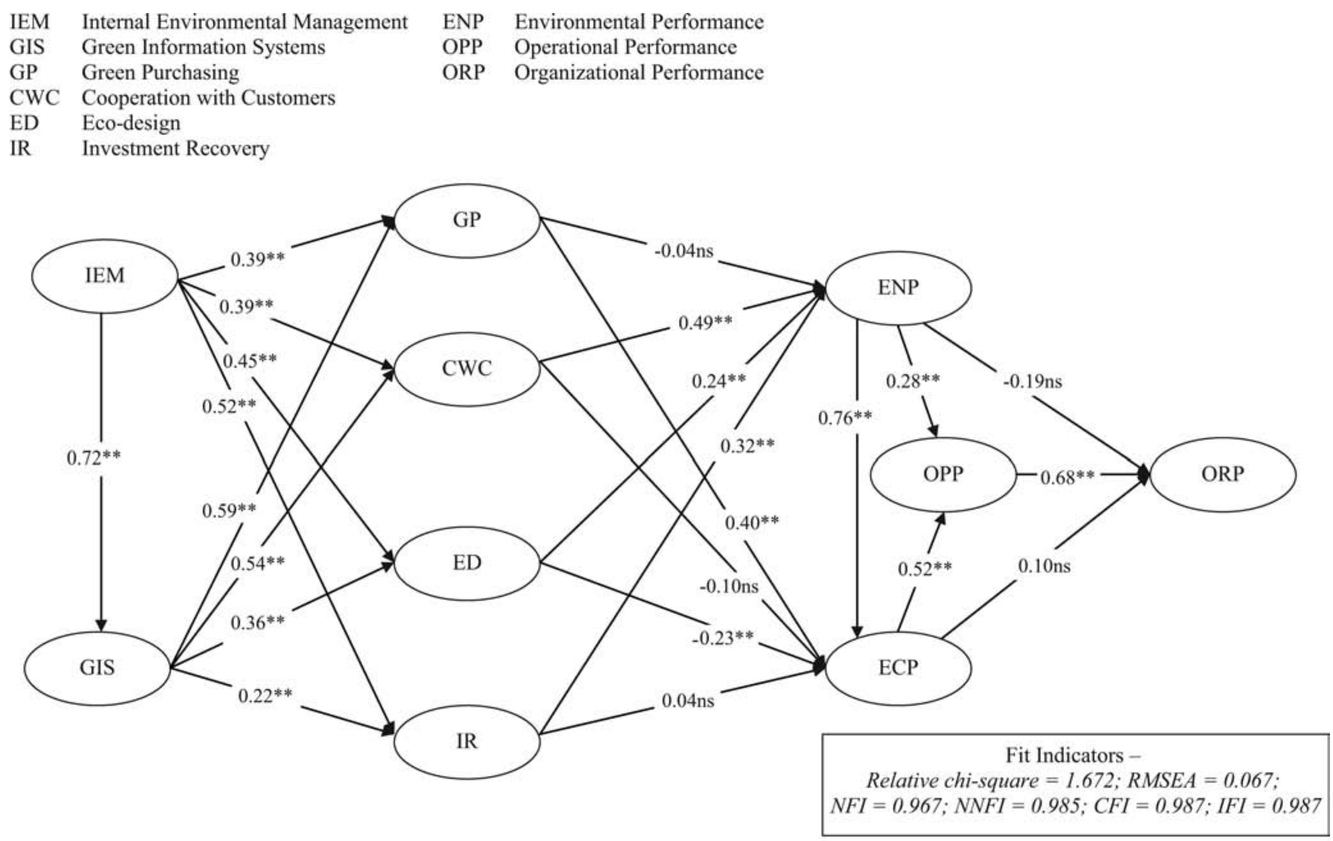
Variable	Minimum	Maximum	Mean	Std deviation	Skewness	Kurtosis
Internal environmental management	1.00	5.00	3.201	1.294	−0.278	−1.026
Green information systems	1.00	5.00	3.198	1.102	−0.301	−0.542
Green purchasing	1.00	5.00	2.909	1.319	−0.012	−1.161
Cooperation with customers	1.00	5.00	3.222	1.341	−0.235	−1.188
Eco-design	1.00	5.00	3.421	1.279	−0.493	−0.828
Investment recovery	1.00	5.00	3.776	1.147	−0.916	−0.032
Environmental performance	1.00	5.00	3.539	1.030	−0.607	0.119
Economic performance	1.00	5.00	3.294	1.177	−0.391	−0.684
Operational performance	1.00	5.00	3.637	1.016	−0.584	−0.005
Organizational performance	1.00	5.00	3.384	0.924	−0.289	0.139

Table V Correlation matrix

	IEM	GIS	GP	CWC	ED	IR	ENP	ECP	OPP	ORP
IEM	1									
GIS	0.665*	1								
GP	0.715*	0.783*	1							
CWC	0.694*	0.732*	0.828*	1						
ED	0.610*	0.599*	0.680*	0.704*	1					
IR	0.550*	0.496*	0.562*	0.568*	0.629*	1				
ENP	0.657*	0.666*	0.665*	0.748*	0.691*	0.640*	1			
ECP	0.625*	0.663*	0.616*	0.625*	0.512*	0.533*	0.736*	1		
OPP	0.547*	0.547*	0.553*	0.532*	0.482*	0.543*	0.657*	0.662*	1	
ORP	0.423*	0.435*	0.436*	0.391*	0.330*	0.332*	0.316*	0.382*	0.557*	1

Notes: * indicates significance at the 0.01 level; IEM = Internal environmental management; GIS = Green information systems; GP = Green purchasing; CWC = Cooperation with customers; ED = Eco-design; IR = Investment recovery; ENP = Environmental performance; ECP = Economic performance; OPP = Operational performance; ORP = Organizational performance

Figure 2 Comprehensive green supply chain management practices performance model with SEM results



Notes: *significant at 0.05 level; **significant at 0.01 level; ns: not significant

consumption. Green purchasing is not significantly linked to environmental performance but is positively linked to economic performance. Cooperation with customers is positively associated with both environmental and economic performance. Eco-design is positively linked to environmental performance but is negatively associated with economic performance. Eco-design capability to reduce environmental pollutants is counterbalanced by increases in associated costs perhaps related to materials purchases. Investment recovery is positively associated with environmental performance but not economic performance. It should be noted each of the stage two practices is positively associated with either environmental performance or economic performance. Only eco-design is negatively and significantly associated to either performance measure.

The performance constructs are related as hypothesized with two exceptions. Neither environmental performance nor economic performance is directly related to organizational

Table VI Structural model results

Model link	Std coefficients	Support
Hypotheses tests		
IEM →		
GIS	0.72*	*H1*: supported
GP	0.39*	*H2a*: supported
CWC	0.39*	*H2b*: supported
ED	0.45*	*H2c*: supported
IR	0.52*	*H2d*: supported
GIS →		
GP	0.59*	*H3a*: supported
CWC	0.54*	*H3b*: supported
ED	0.36*	*H3c*: supported
IR	0.22*	*H3d*: supported
GP →		
ENP	−0.04ns	*H4a*: not supported
ECP	0.40*	*H5a*: supported
CWC →		
ENP	0.49*	*H4b*: supported
ECP	−0.10ns	*H5b*: not supported
ED →		
ENP	0.24*	*H4c*: supported
ECP	−0.23*	*H5c*: not supported
IR →		
ENP	0.32*	*H4d*: supported
ECP	0.04ns	*H5d*: not supported
ENP →		
ECP	0.76*	*H6a*: supported
OPP	0.28*	*H6b*: supported
ORP	−0.19ns	*H6c*: not supported
ECP →		
OPP	0.52*	*H7a*: supported
ORP	0.10ns	*H7b*: not supported
OPP →		
ORP	0.68*	*H8*: supported

Notes: *Significant at 0.01 level; Chi-square ratio = 1.672; RMSEA = 0.067; NFI = 0.967; NNFI = 0.985; CFI = 0.987; IFI = 0.987; IEM = Internal Environmental management; ENP = Environmental performance; GIS = Green information systems; OPP = Operational performance; GP = Green purchasing; ORP = Organizational performance; CWC = Cooperation with customers; ED = Eco-design; IR = Investment recovery

performance. Both environmental performance and economic performance are positively associated with operational performance which, in turn, is strongly associated with organizational performance. Operational performance reflects the organization's ability to satisfy customers in terms of on-time delivery of quality products and the ability to do so more efficiently through reduced inventory and scrap levels. Environmental performance and economic performance enhance operational performance which enhances organizational performance.

5. Conclusions

5.1 Discussion of findings

We theorize and assess a comprehensive GSCM practices model. While all of the individual hypotheses are not supported, the general model holds together reasonably well. The significance and strength of the positive links among the stage one and stage two GSCM practices suggest the importance of a staged implementation of the practices. These results are straightforward leaving little doubt as to the recommended ordering.

As the model depicts, environmental sustainability must first be adopted as a strategic imperative. This requires that top-level management work to incorporate environmental sustainability as a key part of the organization's mission statement and that the necessity to develop processes and deliver products and services that are environmentally friendly be communicated throughout all levels of the organization. There is considerable evidence linking supply chain success to the ability of ERP information systems to facilitate information sharing among supply chain partners (Green *et al.*, 2007). Because environmental sustainability is a supply chain level imperative (Vachon and Klassen, 2007), it is important that organizations develop information systems capable of integrating and coordinating environmental sustainability initiatives with suppliers and customers (Esty and Winston, 2006). Adoption of environmental sustainability as strategy through the implementation of internal environmental management practices both directly and indirectly (through green information systems) impacts the stage two GSCM practices. As the firm's SCM strategy expands to incorporate the environmental sustainability imperative, the firm's ERP system must expand to monitor environmental efforts and outcomes in cooperation with customers and suppliers.

The impact of the stage two practices on environmental performance and economic performance is less clear cut. Specifically, the results associated with eco-design are problematic. Grote *et al.* (2007, p. 4100) state the aim of eco-design as "the reduction of a product's environmental impact without creating a negative trade-off with other design criteria, such as costs and functionality." While eco-design is positively associated with environmental performance (beta = 0.24, sig. at 0.01 level), it is negatively associated with economic performance (beta = −0.23, sig. at the 0.01 level). It appears then that eco-design is not fully accomplishing the intended aim. Grote *et al.* (2007) argue that this may be because eco-design methodologies require further development and improvement.

Also surprising is the result that green purchasing does not significantly impact environmental performance, while significantly impacting economic performance. These results are in line with the Zhu and Sarkis (2007) findings for Chinese firms under competitive pressure. As in the Zhu and Sarkis (2007) study, the measurement scales for environmental and economic performance were completed by manufacturing managers focusing on the plant level. As measured, the environmental impact of green purchasing may lie with the supplier rather than manufacturer, while still positively impacting economic performance for the manufacturer. As Zhu and Sarkis (2007) argue green purchasing is less costly for manufacturers to implement that other green practices such as eco-design.

Cooperation with customers directly impacts environmental performance but does not directly impact economic performance. Instead, cooperation with customers indirectly impacts economic performance through environmental performance. Of the four green constructs linked to environmental performance in the model, cooperation has the largest impact followed by investment recovery and eco-design. Zhu and Sarkis (2007) did not find cooperation with customers to be significantly associated with either environmental or economic performance for manufacturers under pressure from customers to adopt environmental practices in China. The difference in results may be attributed to differences in the samples employed. Our sample is made up of a diverse group US manufacturers, while the sample used by Zhu and Sarkis (2007) and Zhu *et al.* (2008a) is made up of a more focused group of Chinese manufacturers. Our use of a diverse group from a different country serves to establish the validity of the measurement scales across manufacturers and countries as recommended by Zhu *et al.* (2008a). It may be that US manufacturers are more market oriented and, therefore, are more responsive to changes in customer demand related to environmental expectations. As Zhou *et al.* (2008) note, Chinese firms have only recently begun to embrace market orientation as a means to survive intensified competition. This may explain the finding that cooperation with customers is strongly associated with environmental performance for the US sample.

Investment recovery directly impacts environmental performance but does not directly impact economic performance as hypothesized for the US sample. Zhu and Sarkis (2007) did not find a positive association for investment recovery with environmental performance for the Chinese sample. They also found that investment recovery positively impacts economic performance under conditions of regulatory and competitive pressures but not market pressure. We generally found the opposite for the US sample. Investment recovery leads to significant environmental improvement but does not directly impact economic performance. The impact of investment recovery on economic performance is indirect through environmental performance. These contradictory results may also be explained by differences in the samples. As Zhu *et al.* (2008c, p. 331) note, "[investment recovery] has received much less attention in China than in other countries such as the U.S. and Germany."

Because all of the stage two practices are positively associated with either environmental performance or economic performance, we assert that this portion of the model also holds promise. Finally, the relationships among the performance constructs seem to make logical sense. Environmental performance and economic performance leverage improved operational performance which leads to improved organizational performance.

5.2 Limitations of the study

We propose and assess a comprehensive GSCM practices performance model. It is our belief that the primary contribution of this study lies in the comprehensive nature of the model as opposed to parsing and assessing pieces of the model. This approach stretches the limits of the sample, however. Rather than adopt the traditional path analysis methodology indicated by the large number of constructs compared to the small sample size, we have chosen to push the limits of structural equation modeling in an effort to assess the fit of the entire model to the data. It was necessary to reduce the number of measurement scale items from 57 to 38 to ensure that the degrees of freedom exceed the number of parameters estimated.

5.3 Future research

Because this is the first testing of the comprehensive theoretical model, it is important that the model be assessed using data from additional samples. In comparing the results with those reported by Zhu and Sarkis (2007) differences were noted concerning the impact of cooperation with customers and investment recovery on environmental and economic performance. The differences may be attributable to differences in the sample, US manufacturers for this study and Chinese manufacturers in the Zhu and Sarkis (2007) study. Further research is necessary to reconcile these differences. It is also important to verify the findings using a larger sample. In addition, this research focuses on the implementation of GSCM practices by manufacturing organizations. The model should be modified to reflect other organization types, such as wholesalers and retailers, and data should be collected to assess the impact of supply chain practices on the organizational performance of these different types of organizations.

We developed a GSCM model focusing on GSCM practices implemented by manufacturing organizations to integrate and coordinate environmental sustainability efforts with immediate supply chain partners and the impact of those practices on performance. While it is important to evaluate each of the individual associations depicted within the model, it is more important to consider the model as a whole and how well the model reflects reality. The model level results imply that the implementation of GSCM practices should be considered within the context of the supply chain and the existing functioning business processes that extend throughout the supply chain. Considering the contextual approach, it is important to assess constructs representing other improvement programs such as JIT, TQM, lean manufacturing, and agile manufacturing as potential antecedents to GSCM practices. For example, it is likely that the capability that JIT organizations have to eliminate wastes will support efforts to eliminate environmental wastes.

5.4 Implications for practitioners

We argue that environmental sustainability is a supply chain level imperative and provide evidence supporting the need for manufacturing organizations to implement GSCM practices in collaboration with suppliers and customers. Manufacturing managers have had to develop SCM knowledge and skills in addition to the knowledge and skills necessary to manage at the organizational level. Manufacturing managers must now focus on improving the supply chain in order to improve organizational performance. We reiterate the importance that organizations adopt SCM strategies and work to improve the processes that extend throughout the supply chain to better satisfy the final customers of the supply chain. From a very practical view, however, manufacturing managers are held responsible for the performance of their organizations. If improving the supply chain and satisfying final customers finally results in improved organizational performance, organizational managers will adopt such an approach. We set out to discover whether the adoption of GSCM practices focused on collaboration with suppliers and customers will lead to improved environmental performance and consequently improved organizational performance.

The theorized and empirically supported model offers a structured approach to the successful implementation of an environmental sustainability strategy that requires that manufacturers work directly with both suppliers and customers to achieve desired results – an improved environment with an accompanying improvement in firm performance. It is important to adopt environmental sustainability as a strategic imperative and to modify existing enterprise information systems to monitor the processes and outcomes related to the organization's sustainability initiatives prior to the implementation of the green practices. Once environmental sustainability has become a strategic focus and information systems have been modified to monitor efforts to become environmentally sustainable, manufacturers can begin to implement sustainability practices with some degree of confidence that the practices will yield not only improved environmental and economic performance but improved operational and organizational performance. The adoption of GSCM practices improves the organization's capabilities to sustain the environment and to strengthen the organization's economic viability.

Major manufacturers have begun to implement comprehensive programs to control environmental practices throughout their supply chains (Vachon, 2007). Specific activities that support environmental collaboration, monitoring, and control include:

- monitoring reverse flows of materials;
- sharing techniques and knowledge related to environmental management with supply chain partners;
- working to control the environmental risk associated with suppliers' operations; and
- working to assure proper product use (Vachon, 2007).

Vachon (2007, p. 4357) asserts, "Ultimately, such activities with suppliers or with customers can affect environmental management decisions within any particular manufacturing plant." The items in the GSCM practices scales (Appendix) developed by Zhu *et al.* (2008a) also delineate characteristics of manufacturers that practice environmental collaboration and monitoring with suppliers and customers. These characteristics provide more specific direction to manufacturers working to extend environmental practices throughout their supply chains.

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Appendix. Measurement scales

Internal environmental management (Zhu *et al.*, 2008a)
Please indicate the extent to which you perceive that your plant is implementing each of the following. (Five-point scale: 1 = not considering it; 2 = planning to consider it; 3 = considering it currently; 4 = initiating implementation; 5 = implementing successfully)

- Commitment of GSCM from senior managers.
- Support for GSCM from mid-level managers.
- Cross-functional cooperation for environmental improvements.
- Total quality environmental management.
- Environmental compliance and auditing programs.
- ISO 14001 certification.
- Environmental Management Systems.

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).

- Reducing transportation costs.
- Supporting team work and meetings of globally distributed employees to limit their air travel.
- Tracking environmental information (such as toxicity, energy used, water used, air pollution.

- Monitoring emissions and waste production.
- Providing information to encourage green choices by consumers.
- Improving decision making by executives by highlighting sustainability issues.
- Reducing energy consumption.
- Supporting the generation and distribution of renewable energy.
- Limiting carbon and other emissions.
- Identifying the role of IS in energy policy.

Green purchasing (Zhu *et al.*, 2008a)
Please indicate the extent to which you perceive that your plant is implementing each of the following. (Five-point scale: 1 = not considering it; 2 = planning to consider it; 3 = considering it currently; 4 = initiating implementation; 5 = implementing successfully).
- Eco labeling of products.
- Cooperation with suppliers for environmental objectives.
- Environmental audit of suppliers' internal management.
- Suppliers' ISO 14000 certification.
- Second-tier supplier environmentally friendly practice evaluation.
- Providing design specification to suppliers that include environmental requirements for purchased item.

Cooperation with customers (Zhu *et al.*, 2008a)
Please indicate the extent to which you perceive that your plant is implementing each of the following. (Five-point scale: 1 = not considering it; 2 = planning to consider it; 3 = considering it currently; 4 = initiating implementation; 5 = implementing successfully).
- Cooperation with customers for eco design.
- Cooperation with customers for cleaner production.
- Cooperation with customers for green packaging.
- Cooperation with customers for using less energy during product transportation.

Eco-design (Zhu *et al.*, 2008a)
Please indicate the extent to which you perceive that your plant is implementing each of the following. (Five-point scale: 1 = not considering it; 2 = planning to consider it; 3 = considering it currently; 4 = initiating implementation; 5 = implementing successfully).
- Design of products for reduced consumption of material/energy.
- Design of products for reuse, recycle, recovery of material and/or component parts.
- Design of products to avoid or reduce use of hazardous products and/or their manufacturing process.

Investment recovery (Zhu *et al.*, 2008a)
Please indicate the extent to which you perceive that your plant is implementing each of the following during the past year. (Five-point scale: 1 = not considering it; 2 = planning to consider it; 3 = considering it currently; 4 = initiating implementation; 5 = implementing successfully).
- Investment recovery (sale) of excess inventories/materials.
- Sale of scrap and used materials.
- Sale of excess capital equipment.

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. (Five-point scale: 1 = not at all; 2 = a little bit; 3 = to some degree; 4 = relatively significant; 5 = significant).
- Reduction of air emissions.
- Reduction of effluent waste.
- Reduction of solid wastes.
- Decrease in consumption for hazardous/harmful/toxic materials.
- Decrease in frequency for environmental accidents.
- Improvement in an enterprise's environmental situation.

Economic 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. (Five-point scale: 1 = not at all; 2 = a little bit; 3 = to some degree; 4 = relatively significant; 5 = significant).
- Decrease in cost of materials purchasing.
- Decrease in cost for energy consumption.
- Decrease in fee for waste treatment.
- Decrease in fee for waste discharge.
- Decrease in fine for environmental accidents.

Operational 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. (Five-point scale: 1 = not at all; 2 = a little bit; 3 = to some degree; 4 = relatively significant; 5 = significant).
- Increase in the amount of goods delivered on time.
- Decrease in inventory levels.
- Decrease in scrap rate.
- Increase in product quality.
- Increase in product line.
- Improved capacity utilization.

Organizational performance (Green and Inman, 2005)
Please rate your organization's performance in each of the following areas as compared to the industry average (1 = well below industry average, 5 = well above industry average).
- Average return on investment over the past three years.
- Average profit over the past three years.
- Profit growth over the past three years.
- Average return on sales over the past three years.
- Average market share growth over the past three years.
- Average sales volume growth over the past three years.
- Average sales (in dollars) growth over the past three years.

About the authors

Kenneth W. Green Jr is 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

Pamela J. Zelbst is a PhD from University of Texas at Arlington and is an Associate Professor of Management at Sam Houston State University. Her research appears in the *International Journal of Operations & Production Management*, *Journal of Behavioral and Applied Management*, *Industrial Management & Data Systems*, *Journal of Business and Industrial Marketing*, *Management Research Review*, and *International Journal Management in Education*.

Jeramy Meacham is a PhD from Jackson State University and is an Assistant Professor of Management at Southern Arkansas University. His research interests include information systems, supply chain management, knowledge management, and healthcare quality and outcomes. His research has appeared in the *Journal of Information and Knowledge Management*. He has presented several research papers in leading national conferences.

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. He has presented several papers at the Americas Conference of Information Systems, the annual conferences of the Decision Sciences Institute, and other regional conferences.