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Impact of JIT, TQM and green supply chain practices on environmental sustainability

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Abstract

Purpose – The purpose of this paper is to empirically assess the complementary impact of JIT, TQM and green supply chain practices on environmental performance.
Design/methodology/approach – Data from a sample of 225 US manufacturing managers are analyzed using a PLS-SEM methodology.
Findings – JIT and TQM are directly and positively associated with green supply chain management practices. JIT, TQM and green supply chain practices are complementary in that combined they provide a greater impact on environmental performance than if implemented individually.
Research limitations/implications – The sample is limited to US manufacturing managers, with a low response rate.
Practical implications – Successful implementations of JIT and TQM improvement programs support the implementation of green supply chain management practices leading to improved environmental performance.
Social implications – The combination of JIT, TQM and green manufacturing practices improves the environment by eliminating all forms of waste and providing customers with eco-friendly products and services.
Originality/value – This study is one of the first to empirically assess the complementary impact of JIT, TQM and green supply chain practices within the context of environmental sustainability.

Keywords Total quality management, Environmental management, Green manufacturing, Just-in-time

Paper type Research paper

1. Introduction

Manufacturing organizations must respond to changes in the demands of both immediate and ultimate customers. As these customers begin to demand eco-friendly products and services that are produced by processes that do not damage the environment, manufacturing organizations must modify operations to reflect these new customer demands (Green *et al.*, 2015; Clark *et al.*, 2014).

It has been empirically established that green supply chain management practices lead to improved environmental performance (Zhu *et al.*, 2008) and also improved organizational performance (Green *et al.*, 2012). It is important to identify necessary antecedents to the implementation of green supply chain management practices. Additional research that identifies and assesses the impact of such antecedents is needed. In this study, we examine the combined impact that Just-in-time (JIT) and total quality management (TQM), two elements of lean (Shah and Ward, 2003) that have been called the main lean manufacturing bundles (Furlan *et al.*, 2011), and green supply chain practices have on environmental performance. More generally speaking, can the established capability to eliminate all forms of waste (JIT) and to produce and deliver products that precisely match customer specifications (TQM) have

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a significant impact on the ability of manufacturing organizations to successfully implement environmental sustainability improvement programs resulting in improved environmental performance? Specifically, are JIT, TQM and environmental supply chain practices complementary in that the three combined impact environmental performance more than the impact of the three in isolation?

Florida and Davison (2001) describe a "three zero manufacturing paradigm" that calls for manufacturing managers to simultaneously strive to achieve zero inventory, zero defects and zero environmental waste and emissions. Intuitively, this paradigm could be practically affected through a combination of JIT, TQM and green supply chain management practices. Both JIT and TQM have been heavily researched and established as programs that lead to improved organizational performance via a focus on the elimination of all waste from all processes, the requirements of a customer focus and the production of quality goods and services that precisely meet customer requirements (Zelbst *et al.*, 2010).

Since JIT and TQM focus on the elimination of wastes associated with inefficiency and ineffectiveness, do they significantly support efforts to achieve environmental sustainability? We develop and empirically assess a model that incorporates JIT, TQM, green supply chain management practices and environmental performance constructs using data from a sample of US manufacturing managers in an effort to answer this research question.

While most of the individual hypotheses in the model have been previously assessed, we find no previous work that combines the management improvement programs of JIT, TQM and green supply chain management practices as antecedents to environmental performance in the context of a structural model. There are studies that assess the individual impacts of JIT, TQM and green supply chain management practices on environmental performance and those that assess the impact of lean on environmental practices/performance (Inman and Green, 2018) but none that assess the combined impact of the three specific initiatives of JIT, TQM and green supply chain practices on environmental performance. These individual sets of practices are complementary and it is important to assess their combined impact on environmental sustainability as measured by environmental performance. Our primary contribution is therefore to assess the combined impact of JIT, TQM and green supply chain practices on environmental performance. The model is constructed in such a way as to formally establish JIT and TQM as necessary antecedents to green supply chain practices and environmental performance. We believe that the results of this formal assessment within the context of a structural model will make a significant new contribution to the environmental sustainability literature informing manufacturing managers of the importance of implementing these specific sets of practices in combination to significantly improve the environmental performance of their manufacturing organizations.

A review of the literature which includes a description of the theorized model is followed by a discussion of the methodology employed to answer the research question related to whether JIT and TQM are required antecedents to the development of environmental sustainability competencies or whether, when combined with environmental practices, an even greater result is achieved. The results of the statistical analysis and conclusions based on the results are then presented.

2. Literature review and hypotheses

This section is organized such that the complementary theory is first described and discussed as the basis for this study. Following a discussion of this general theory, the theoretical model that pictures the relationships among the study constructs is presented. This model illustrates how the endogenous constructs of JIT, TQM and green supply chain practices may combine to positively impact the exogenous construct environmental performance. Finally, hypotheses representing each of the links in the theorized model are developed and supported.

2.1 Complementarity as theoretical basis for study

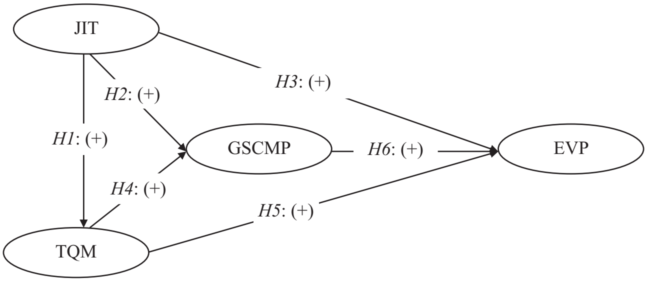
The theoretical basis for this study is the complementarity theory (Narasimhan *et al.*, 2010; Bergmiller and McCright, 2009; Milgrom and Roberts, 1990). Organizations can gain competitive advantage by developing combinations of operational competencies. Specifically, the combination of JIT, TQM and green supply chain management practices are organizational competencies that may yield competitive advantage when combined by manufacturing organizations. JIT, TQM and green supply chain management practices are complementary in that the sets of practices are mutually supportive. The combination of related practices leads to a higher level of environmental sustainability than can be achieved when the sets of practices are individually implemented.

Fliedner and Majeske (2010) describe sustainability as the next stage in the evolution of lean as it goes beyond the waste elimination of Ohno's seven lean principles. Under-utilization of creative employees is considered the eighth waste with environmental waste deemed the ninth (Vinodh *et al.*, 2011). This ninth waste implies unnecessary or excessive use of resources as well as harmful substances released into the environment (Vinodh *et al.*, 2011). Since the primary goal of JIT is to reduce and eliminate waste (Wu *et al.*, 2012) and TQM is about making things right the first time, zero defects, customer satisfaction and continuous improvement (Sower, 2011), it is logical to assert that environmental sustainability initiatives are more likely to thrive in an organizational environment that already incorporates JIT and TQM within its production processes. This is possibly due to wastes, targeted by lean, that have environmental impacts embedded within them (Larson and Greenwood, 2004).

JIT and TQM have been shown to work together synergistically to improve performance, meaning the two together create greater cost efficiencies than if either were pursued alone (Wu *et al.*, 2012). Previous research has shown lean manufacturing and environmental sustainability to be not only compatible but complementary thereby creating a synergy that results in improved environmental and business performance (Azevedo *et al.*, 2012; Bergmiller and McCright, 2009; Larson and Greenwood, 2004; Vinodh *et al.*, 2011). Young (2009) proposed that successful JIT and TQM programs have prepared manufacturers to embrace environmental sustainability programs and practices; therefore, it is logical, based on complementarity theory, to propose that the combined impact of JIT and TQM practices on environmental practices could result in more improvement than each implemented in isolation. To test for synergy, one or more programs must be shown to provide a positive impact on the results of another program (Bergmiller and McCright, 2009). We argue that JIT, TQM and environmental practices have complementary capabilities that combine to magnify an organization's ability to achieve environmental sustainability.

2.2 Theoretical model

Figure 1 incorporates seven hypotheses. Generally, the model is structured to facilitate assessment of the impact of JIT and TQM practices on environmental sustainability represented as the implementation of green supply chain management practices and improved environmental performance. JIT practices are hypothesized as positively associated with TQM practices, green supply chain management practices and environmental performance. TQM practices are hypothesized as positively associated with green supply chain management practices and environmental performance. As a result of complementarity, JIT, TQM and green supply chain practices combined are hypothesized as having a greater impact on environmental performance than the impact of the individual initiatives. Finally, green supply chain management practices are hypothesized as positively associated with environmental performance.



Notes: JIT: unique JIT practices; TQM: unique TQM practices; GSCMP: green supply chain management practices; EVP: environmental performance

Figure 1. Structural model with hypotheses

2.3 Hypotheses

The relationship between JIT and TQM practices is well documented. Vokurka *et al.* (2007, p. 14) assert that "Just-in-time is closely correlated with TQM, with the ultimate goal of meeting or exceeding customer requirements." Other researchers have concluded that JIT practices and TQM practices combine and interact to generate synergies that result in improved performance (Dean and Snell, 1996; Flynn *et al.*, 1995). Dreyfus *et al.* (2004) found that effective implementation of TQM is enhanced by JIT implementation. Additionally, Eker and Pala (2008) found a moderately strong, positive correlation between JIT and TQM practices while Zelbst *et al.* (2010) reported a moderately strong, positive association between JIT and TQM practices based on an analysis of US manufacturers. More recently, Chen (2015) found a very strong positive relationship between JIT and TQM based on analysis of a sample of Chinese manufacturers. Within the structural model theorized by Zelbst *et al.* (2010), JIT is assessed as an antecedent to TQM with the results supporting this relationship. Hence, we propose that:

H1. JIT practices are directly and positively associated with TQM practices.

Carvalho *et al.* (2011, p. 171) list the main green supply chain practices as: "reduction of redundant and unnecessary materials, introduction of reusable and remanufactured parts in the material inventory, reduction of replenishment frequency, integration of the reverse material and information flow in the supply chain, environmental risk-sharing, waste minimization, reduction of transportation lead time and the efficiency of resource consumption." JIT is an improvement program designed to eliminate forms of waste from supply, production and delivery processes, and promote the optimal use of resources throughout these processes (Inman *et al.*, 2011; Wu *et al.*, 2012), practices that intuitively should enhance and support the use of green supply chain management practices. Certain elements of JIT, JIT-purchasing and JIT-selling require integration and coordination with suppliers and customers (Freeland, 1991; Germain and Dröge, 1997; Green and Inman, 2005). Existing cooperative associations, such as those found in certain elements of JIT (JIT-purchasing and JIT-selling), should support expanding the focus on environmental sustainability through green supply chain management practices such as green purchasing and cooperation with customers. Young (2009) reports that a group of Australian organizations leveraged existing JIT capabilities to support environmental sustainability efforts with good results. Within our study, JIT is assessed as antecedent to green supply chain management practices, suggesting that:

H2. JIT practices are directly and positively associated with green supply chain management practices.

Zhu and Sarkis (2004) noted that the lean manufacturing aspect of JIT could contribute to improved environmental performance, but found the relationship between green practices and environmental performance to be weaker in firms having more JIT practice adoption. However, Klassen (2000) found investment in JIT systems to be positively and significantly associated with environmental performance. Therefore, we propose that:

H3. JIT practices are directly and positively associated with environmental performance.

Young (2009) reports on the results of a group of Australian organizations that leveraged existing TQM capabilities to support environmental sustainability efforts. Because TQM focuses on producing goods and services that precisely meet customer specifications, these organizations were able to optimize resource allocation and use (Young, 2009). Additionally, as customers begin to demand products and services that are environmentally friendly, the TQM customer focus will facilitate the incorporation of environmental sustainability as customer requirements resulting in the production of products and services that do not damage the environment (Green *et al.*, 2012; Zelbst *et al.*, 2010). Zhu and Sarkis (2004, p. 283) argue that quality management is an "important antecedent" to the successful implementation of many green supply chain management practices. Garza-Reyes *et al.* (2018) assess the utilization of total quality environmental management (TQEM) which focuses TQM capabilities on eliminating environmental wastes. Their discussion related to TQEM suggests that TQM practices and environmental sustainability practices are compatible and positively linked. Here, we assess TQM as an antecedent to green supply chain management practices as Zhu and Sarkis (2004) suggest:

H4. TQM practices are directly and positively associated with green supply chain management practices.

Over the years, TQM has shifted from a purely statistical view of process control to a strong internal and external customer orientation (Klassen and McLaughlin, 1993). It has been described as an integrative approach for the pursuit of customer satisfaction (Zee *et al.*, 2011) which requires both a customer focus and control of processes to eliminate the production of defective products and services (Flynn *et al.*, 1995). Hong *et al.* (2012) found that firms striving to respond to markets and customers also improved environmental performance. Therefore, as customers begin to demand products and services that are environmentally friendly, the customer focus component of TQM should support the production of environmentally sustainable goods and services through processes that do not damage the environment (Green *et al.*, 2012). Additionally, if resources are optimally employed via the elimination of waste, improved environmental performance should be supported. TQM efforts, when directed toward environmental issues, appear to result in positive outcomes (Golicic and Smith, 2013). We propose the following hypothesis:

H5. TQM practices are directly and positively associated with environmental performance.

Green supply chain management practices are designed to improve environmental performance (Green *et al.*, 2012; Zhu and Sarkis, 2004). These practices can reduce the ecological impact (e.g. minimizing ecological damage) through practices focused on improving environmental performance by reducing air emissions and the discharge of effluent and solid wastes, and the reduction of use of hazardous and toxic materials in production processes, without sacrificing quality, cost reliability or energy efficiency (Carvalho *et al.*, 2011). The link between green supply chain management practices and environmental performance has been empirically established through prior research. Zhu and Sarkis (2004) found strong support for their hypothesis that "enterprises having higher levels of adoption of green supply chain management practices will have better environmental performance improvements." Inman and Green (2018), Green *et al.* (2012) and Li *et al.* (2016) also found that green supply chain management practices positively impact environmental performance, leading to the following hypothesis:

H6. Green supply chain management practices directly and positively affect environmental performance.

There are a number of papers which address the integration of lean manufacturing and green manufacturing utilizing survey research (Klassen, 2000; Zhu and Sarkis, 2004; Green *et al.*, 2012; Hajmohammad *et al.*, 2013; Prasad *et al.*, 2016; Inman and Green 2018). However, these papers look at the "overall" picture of lean as the "bundles" of JIT, TQM, total preventive maintenance and Human Resource management as defined by Shah and Ward (2003), while our work concentrates on the relationship between two of these elements, JIT and TQM, and environmental practices. There is also published research available validating the complementary relationship between JIT and TQM (Flynn *et al.*, 1995; Furlan *et al.*, 2011, Chen, 2015). However, none specifically address the complementary relationship between integrated JIT/TQM and environmental practices. Hallam and Contreras (2016) reviewed 60 articles pertaining to the integration of lean and green and found that most were conceptual papers (only ten utilized survey data) with little evidence of combined lean manufacturing and green manufacturing. Since they (Hallam and Contreras, 2016) did note a purported synergy between lean and green in the postulate of some articles, we hypothesize that:

H7. JIT, TQM and green supply chain practices together have a greater impact on environmental performance than individually.

3. Methodology

3.1 Sampling process

Data were collected from a sample of plant-level managers working for US manufacturing organizations. The data were collected during the spring of 2012 via an online data service (Zoomerang through MarketTools, Inc.). This data collection process was managed by Zoomerang and was structured to ensure unique responses from validated members of the manufacturing panel. Such an online data collection methodology has been found to be effective in eliciting responses from manufacturing managers (Green *et al.*, 2012; Inman *et al.*, 2011).

The manufacturing panel includes individuals working for US manufacturing plants who hold both managerial and operational positions. Filtering questions were used to ensure that data from only individuals who hold manufacturing manager positions are used in the study. Potential respondents were first asked "Are you a manager (supervising at least two employees) currently working at a manufacturing plant in the United States?" Individuals answering "no" to this question were screen from further data collection. A second question "Which of the following categories best describes your current position?" was then asked to specifically identify the type of manager responding (see Table I for categories). Individuals answering "other" to this question were not included in the subsequent data analysis. This double questioning approach was designed to ensure that data only from manufacturing managers working for US manufacturing plants was captured. It should be noted that Zoomerang was unable to provide a sample frame strictly made up of manufacturing managers such as plant and operations managers. It was necessary to extend invitations to 4,660 members of a panel that included individuals working for manufacturing firms, whether or not they held manufacturing manager positions.

Ultimately, data from 225 manufacturing managers likely to have the necessary knowledge to fully complete the survey were included in the data set subsequently analyzed. All of the respondents hold plant-level management positions in manufacturing organizations. The sample is comprised of a relatively diverse group of US manufacturing managers.

Title	Number
Operations manager	66
Purchasing manager	41
Engineering manager	29
Quality manager	28
Plant manager	25
Information systems manager	16
Logistics manager	9
Environmental sustainability manager	6
Supply chain manager	5
Total	225
Industry category	
Food manufacturing	18
Beverage and tobacco product manufacturing	3
Textile mills	1
Textile product mills	8
Apparel manufacturing	1
Leather and allied product manufacturing	4
Wood product manufacturing	13
Paper manufacturing	7
Printing and related support activities	4
Petroleum and coal products manufacturing	1
Chemical manufacturing	18
Plastics and rubber products manufacturing	16
Non-metallic mineral product manufacturing	1
Primary metal manufacturing	12
Fabricated metal product manufacturing	17
Machinery manufacturing	17
Computer and electronic product manufacturing	9
Electrical equipment manufacturing	2
Transportation equipment manufacturing	6
Furniture and related product manufacturing	1
Miscellaneous manufacturing	66
Total	225
Mean years in current position	9.91
Mean number of plant employees	593.66

Table I.
Sample demographics summary

Table I provides a demographic description of the sample. The sample is comprised of a relatively diverse group of US manufacturing managers. It was our original intent to draw data from a broad array of US manufacturing categories and manufacturing management categories for the purpose of supporting generalization of the results fully across the US manufacturing sector (Green *et al.*, 2012; Inman and Green, 2018).

The effective response rate is 4.82 percent (225 divided by 4,660). It should be noted that, because the sample frame included both managers and operational employees working for US manufacturing plants, this response rate is much understated as to the percentage of responding managers. De Beuckelaer and Wagner (2012), Harmon *et al.* (2002) and Larson (2005) all note the difficulty in obtaining responses from manufacturing managers due to the relatively high workloads of those individuals. Inman *et al.* (2011, p. 347) report that "While manufacturing managers are the prime source for supply chain management related data, they are often under severe time and resource constraints making it difficult to achieve high response rates to surveys."

Data were collected over a 13-day period, and responses from early responders (responding during the first three days) and late responders (responding during the last three days) are compared to assess non-response bias as recommended by Armstrong and Overton (1977). A comparison of the means of the descriptive variables and the scale items for the two groups resulted in statistically non-significant differences at either the 0.05 or 0.01 levels. 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 data set.

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 0.574 between green supply chain management practices and organizational performance. The smallest correlation among the relationships specified in the structural model is 0.696 for JIT and environmental performance. Substituting these correlations into the formulas provided by Malhotra *et al.* (2007), the computed z-score is 4.47. This computed z-score corresponds to significance at the 0.01 level. Adjusting for common method variance using the smallest correlation (0.574), the smallest correlation among the hypothesized relationships (0.696) 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).

3.2 Measurement of constructs

The scales incorporated in this study were previously developed and assessed. The JIT and TQM scales are taken from Flynn *et al.* (1995). JIT and TQM are treated as second-order constructs with multiple dimensions. JIT is comprised of kanban, lot size reduction, setup time reduction and JIT scheduling dimensions. TQM incorporates customer focus, product design and statistical process control dimensions. The green supply chain management practices and environmental performance scales are taken from Zhu *et al.* (2008). The green supply chain management practices construct is treated as a second-order construct with the following dimensions: internal environmental management, green purchasing, cooperation with customers, eco-design, and investment recovery. The scales are attached in the Appendix.

3.3 Statistical analysis

Partial least squares structural equation modeling (PLS-SEM) and covariance-based structural equation modeling (CB-SEM) offer alternative approaches to assessing the impact of independent latent constructs on dependent latent constructs within the context of structural models. PLS-SEM is best suited when the objective is prediction and maximization of the explained variance in the dependent latent construct (Matthews *et al.*, 2018; Hair *et al.*, 2011). PLS-SEM is also well suited for hypothesis testing and for assessing models that incorporate second-order constructs (Hair *et al.*, 2011). CB-SEM is more appropriate when the objective is to confirm a theoretical covariance matrix (Matthews *et al.*, 2018; Hair *et al.*, 2011). Hair *et al.* (2017) note that CB-SEM is not suited for prediction. Mathews *et al.* (2018, p. 2) explain that CB-SEM is best when the objective is "theory testing and confirmation" and that PLS-SEM is best when the objective is "prediction, theory development, and explanation." Akter *et al.* (2017) also note that PLS-SEM is suitable when the aim is to capture reality.

Another important distinction between CB-SEM and PLS-SEM relates to ability to assess the overall validity of the theorized structural model. CB-SEM offers global fit indices that suggest how well the theorized model fits the data (Hair *et al.*, 2012). Hair *et al.* (2012) explain that in PLS-SEM, the primary criteria for evaluation of the structural model are the coefficient of determination (R^2) for the endogenous variable and the standardized path coefficients incorporated within the model. Tenenhaus *et al.* (2005) also offer a global fit measure that is applicable when all of the measurement scales supporting the structural analysis are reflective as is the case here.

In this case, we desire to maximize the explained variance for environmental performance resulting from combining JIT, TQM and GSCMP as antecedents. Our model includes a second-order construct and we are primarily interested in predicting the level of environmental performance that results when JIT, TQM and GSCMP are combined as antecedents to environmental performance. For these reasons, PLS-SEM is selected as the most appropriate method for assessing the structural model.

Hair *et al.* (2012) recommend the following general steps to affect PLS-SEM: construct an inner model that reflects the theorized relationships among the latent constructs under study; develop an outer model by associating the observed indicators with the appropriate latent constructs; execute the PLS-SEM algorithm to calculate standardized coefficients for both the inner and outer models as well as generating information necessary to evaluate the validity and reliability of the measurement scales; execute the bootstrapping algorithm to compute the significance levels for each of the linkages for the inner and outer models; and evaluate the quality of the structural model in terms of the variance in the endogenous variable explained by the structural model and the size and significance of the standardized coefficients for the structural links.

The general process recommended by Wetzels *et al.* (2009) for PLS models with second-order constructs is followed. Specifically, SmartPLS 2.0 software developed by Ringle *et al.* (http://SmartPLS.de) is used to conduct the PLS analysis.

4. Results

4.1 Measurement scale assessment

Because the measurement scales were previously developed and assessed (Flynn *et al.*, 1995; Zhu *et al.*, 2008), the scales are assumed to exhibit sufficient content validity. Convergent validity is assessed by reviewing the standardized loadings for each of the first-order constructs with loadings greater than 0.70 indicating sufficient convergent validity (Chiang *et al.*, 2012). The standardized factor loadings are displayed in Table II. All loadings exceed the 0.70 limit with the lowest reported loading of 0.74 for the sixth item in the JIT product design scale. To assess for discriminant validity, the square root of the average variance extracted value for each construct is compared to the correlations with other constructs with square root values greater than the correlations signifying sufficient discriminant validity (Wetzels *et al.*, 2009). Square root of average variance extracted values and construct correlations are displayed in Table III. With the exception of the square root of average variance extracted for internal environmental management and the correlation with green purchasing being equal at 0.89, the square root values for each of the constructs exceeds correlations with other constructs.

Scale reliability is assessed based on Cronbach's α, composite reliability and average variance extracted values (see Table II). All α, composite reliability and average variance extracted values exceed the respective recommended minimums of 0.70, 0.70, and 0.50 recommended by Garver and Mentzer (1999) as demonstrating sufficient scale reliability. The measurement scales exhibit sufficient validity and reliability to support assessment of the hypotheses.

4.2 Structural model assessment

Structural model results are presented in Figure 2. Bootstrapping is used to assess the significance levels of the standardized coefficients. As Hair *et al.* (2011) recommend, the number of samples for the bootstrapping procedure is 5,000 with the number of observations set to 225. The global fit measure (Tenenhaus *et al.*, 2005) for the model is 0.71 which exceeds the cut-off value for large effect sizes of 0.36, as recommended by Wetzels *et al.* (2009). The R^2 value for environmental performance is 0.63. R^2 values between 0.50 and 0.75 indicate that the model has a moderately strong explanatory capability (Hair *et al.*, 2011).

Construct/measures	Loading	CA	CR	AVE
Kanban		0.95	0.96	0.87
KB1	0.92			
KB2	0.95			
KB3	0.93			
KB4	0.93			
Lot size reduction practices		0.88	0.93	0.81
LSRP1	0.90			
LSRP2	0.94			
LSRP3	0.86			
Setup time reduction practices		0.86	0.92	0.86
STRP1	0.86			
STRP2	0.88			
STRP3	0.92			
JIT scheduling		0.83	0.90	74
JITS1	0.79			
JITS2	0.90			
JITS3	0.89			
Customer focus		0.82	0.89	0.73
CF1	0.86			
CF2	0.86			
CF3	0.85			
Product design		0.92	0.93	0.67
PD1	0.83			
PD2	0.82			
PD3	0.83			
PD4	0.83			
PD5	0.83			
PD6	0.74			
PD7	0.86			
Statistical process control		0.86	0.91	0.78
SPC1	0.89			
SPC2	0.92			
SPC3	0.83			
Internal environmental management		0.96	0.96	0.79
IEM1	0.91			
IEM2	0.90			
IEM3	0.92			
IEM4	0.91			
IEM5	0.84			
IEM6	0.87			
IEM7	0.90			
Green purchasing		0.97	0.97	0.85
GP1	0.91			
GP2	0.94			
GP3	0.92			
GP4	0.90			
GP5	0.94			
GP6	0.93			
Cooperation with customers		0.96	0.97	0.90
CWC1	0.95			
CWC2	0.96			
CWC3	0.94			
CWC4	0.95			
Eco-design		0.92	0.94	0.86
ED1	0.93			
ED2	0.93			
ED3	0.92			

(*continued*)

Table II. Psychometric properties of first-order constructs

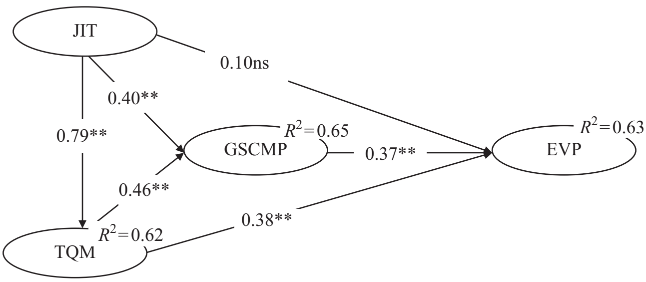
Construct/measures	Loading	CA	CR	AVE
Investment recovery		0.88	0.93	0.81
IR1	0.92			
IR2	0.88			
IR3	0.89			
Environmental performance		0.95	0.96	0.81
ENP1	0.92			
ENP2	0.93			
ENP3	0.89			
ENP4	0.88			
ENP5	0.87			
ENP6	0.92			

Table II.

	KB	LSRP	STRP	JITS	CF	PD	SPC	IEM	GP	CWC	ED	IR	EVP
KB	*0.93*												
LSRP	0.74	*0.90*											
STRP	0.63	0.71	*0.89*										
JITS	0.65	0.64	0.71	*0.86*									
CF	0.45	0.46	0.62	0.54	*0.85*								
PD	0.64	0.59	0.74	0.75	0.73	*0.88*							
SPC	0.66	0.54	0.67	0.66	0.66	0.82	*0.88*						
IEM	0.64	0.57	0.62	0.66	0.56	0.74	0.70	*0.89*					
GP	0.73	0.63	0.64	0.66	0.52	0.70	0.68	0.89	*0.92*				
CWC	0.62	0.54	0.57	0.60	0.53	0.65	0.61	0.81	0.85	*0.95*			
ED	0.52	0.48	0.57	0.62	0.56	0.68	0.64	0.81	0.80	0.86	*0.93*		
IR	0.44	0.47	0.54	0.59	0.59	0.64	0.59	0.67	0.63	0.67	0.78	*0.90*	
EVP	0.60	0.48	0.60	0.69	0.65	0.72	0.65	0.71	0.69	0.66	0.66	0.65	*0.90*

Notes: KB: JIT kanban; IEM: internal environmental management; LSRP: JIT lot size reduction practices; GP: green purchasing; STRP: JIT Setup reduction practices; CWC: cooperation with customers; JITS: JIT scheduling; ED: eco-design; CF: TQM customer focus; IR: investment recovery; PD: TQM product design; EVP: environmental performance; SPC: TQM statistical process control

Table III.
Square root of AVE (diagonal) and correlations among first-order latent constructs



Notes: ns, non-significance. JIT: unique JIT practices; TQM: unique TQM practices; GSCMP: green supply chain management practices; EVP: environmental performance. **Indicates significance at the 0.01 level

Figure 2.
Results of structural assessment

The PLS-SEM results support *H1*, *H2*, *H4*, *H5* and *H6*. *H3* (JIT→EVP) was not supported. JIT practices are positively associated with TQM practices (*H1*) with a standardized coefficient of 0.79 significant at the 0.01 level. JIT practices are also positively associated with green supply chain management practices (*H2*) with a standardized coefficient of 0.40 significant at the 0.01 level. The standardized coefficient for JIT practices to environmental performance (*H3*) of 0.10 is non-significant, indicating that JIT does not directly impact environmental performance within the context of the study model. TQM practices are positively associated with green supply chain management practices (*H4*) with a standardized coefficient of 0.46 significant at the 0.01 level. TQM practices are also positively associated with environmental performance (*H5*) with a standardized coefficient of 0.38 significant at the 0.01 level. Green supply chain management practices are positively associated with environmental performance (*H6*) with a standardized coefficient of 0.38 significant at the 0.01 level.

4.3 Assessment of combined impact

Generally, the results presented in Figure 2 support our assertion that JIT, TQM and green supply chain management combine to positively impact environmental performance. The model incorporating JIT, TQM and green supply chain management explains 63 percent of the variation in environmental performance. Within the context of the model, TQM and green supply chain management directly impact environmental performance while JIT indirectly impacts environmental performance through TQM and GSCMP. It remained unclear at this point, however, whether the combination of practices has a stronger impact than the individual practices.

To verify that the combined impact is stronger than the singular impacts of the practices, the practices were regressed against environmental performance in a stepwise fashion (JIT first, TQM second and GSCMP third) and the incremental improvement in the R^2 value for environmental performance noted. There is theoretical and empirical rationale for this ordering of the practices. Vuppalapati *et al.* (1995) state that:

> Though the Western researchers and practitioners recognized and analyzed JIT as a manufacturing strategy first (in the late 1970s and early 1980s), and then deciphered the broader philosophy of TQM used by successful Japanese companies (mid- and late 1980s), in Japan, JIT, the actual development followed a different evolution […] They developed and implemented the JIT manufacturing techniques as an integral part of the broader TQM philosophy […]. However, since the Western organizations and researchers deciphered the JIT practices first, JIT implementation has preceded TQM adoption in the West.

Since our data are from US manufacturers, we make the assumption that JIT was implemented prior to the implementation of TQM and as such is antecedent to TQM. Additionally, from an analysis of data from a sample of US manufacturing mangers, Zelbst *et al.* (2010) determined JIT to be antecedent to and positively associated with TQM.

The R^2 with only JIT as an antecedent to environmental performance is 0.48. When TQM is added as a second antecedent to environmental performance, the R^2 value increases by 0.10 to 0.58. Finally, when GSCMP is added as a third antecedent, the R^2 value increases by another 0.05 to 0.63. These increments are significant at the 0.01 level, supporting the idea of complementarity among JIT, TQM and environmental practices resulting in elevated environmental performance (*H7*).

While not theoretically justified or empirically supported, an alternate ordering provides some insight into the role that JIT plays in the model. If TQM is first entered into the model without JIT or GSCMP, the R^2 is 0.56. Adding GSCMP next, yields an R^2 of 0.63, the same R^2 that was achieved when JIT was included. Therefore, the subsequent adding of JIT does not increase the R^2 for environmental performance, which is a very surprising result. Possible reasons for this finding are discussed in the next section.

5. Discussion of findings

If we assume that JIT is the foundation for TQM, i.e. antecedent to TQM, our findings indicate that the impact of JIT on environmental performance is indirect through TQM, as *H3* was not supported. Although JIT does not directly impact environmental performance, results indicate that TQM may not be optimized unless JIT has already been fully implemented. Thus theoretical and empirical support is found to support the ordering put forth in our assessment of combined impact (JIT first, TQM second and GSCMP third).

This is consistent with previous research. Dreyfus *et al.* (2004) found that JIT firms implement TQM more rigorously than traditional firms. Also, Chen (2015) proposes a viewpoint where TQM is one part of JIT. Additionally, Nakamura *et al.* (1998) found that JIT alone will not result in optimal plant performance, so it is intuitively logical that the same could hold true for optimal environmental performance. Finally, Vuppalapati *et al.* (1995) note that "all the major elements of JIT are embedded in a more comprehensive TQM campaign" and that "JIT [can] be viewed as a natural component of the overall TQM philosophy" so it is possible that for many, if not most, TQM initiatives, JIT is already a component and is subsumed by the TQM program. Further analysis of our data shows that 64 percent of the respondents scored high (greater than three on the Likert scale) on both JIT and TQM adding further credibility to this proposition.

A more careful analysis provides insight into how the three sets of practices work together to positively impact environmental performance. First, while JIT does not directly impact environmental performance, it indirectly impacts environmental performance through both TQM and GSCMP. The total effect of JIT on GSCMP is 0.448 which is a combination of two indirect effects (0.148 for JIT→GSCMP→EVP plus 0.300 for JIT→TQM→EVP). This combined effect is logical since JIT has been found to be a foundational antecedent to TQM (Zelbst *et al.*, 2014; Zelbst *et al.*, 2010) and the general efficiency capabilities develop through JIT practices applicable when applied to environmental sustainability issues through GSCMP. Second, TQM both directly and indirectly (through GSCMP) impacts environmental performance for a combined impact of 0.55 (0.17 for TQM→GSCMP→EVP plus 0.38 for TQM→EVP). Specifically, the more effective a firm is in providing quality goods and services to customers the more likely the firm will be to work with both customers and suppliers to develop environmentally sustainable practices.

Based on this additional analysis, we conclude that JIT, TQM and GSCMP are complementary practices that combine to improve environmental performance to a greater degree that singular applications of each practice. JIT yields efficiency capabilities that support the efficient management of inventory as it moves through the supply chain; TQM combines effectiveness capabilities to provide customers with quality goods and services; and GSCMP focuses existing JIT and TQM capabilities specifically on providing quality eco-friendly products and services. Customers get quality products and services at a relatively low cost while ensuring environmental sustainability.

6. Conclusions

While there are a number of studies dealing with lean and green, only one other study (Zhu and Sarkis, 2004) was identified that specifically assesses the relationships among JIT, TQM and green supply chain management. Zhu and Sarkis (2004) assess the moderating effect of JIT and TQM practices on the relationship between green supply chain management and environmental performance. While they did find positive correlations among JIT, TQM green supply chain management practices and environmental performance for their Chinese sample, no positive interaction effects were identified for either JIT or TQM. The positive correlations indicate that there are important relationships of some form among JIT, TQM and green supply chain management practices, even though the interaction effects are not positive and significant. As an extension of the research by Zhu and Sarkis (2004), we pose an alternate model that incorporates JIT and TQM as antecedents to green supply chain management practices rather than moderators.

Results reported here indicate that unique JIT and TQM practices combine to support the implementation of green supply chain management practices which lead to improved environmental performance. JIT practices indirectly impact environmental performance through green supply chain management practices and unique practices. TQM practices both directly and indirectly (through green supply chain management practices) impact environmental performance. The results suggest that manufacturing firms with established JIT and TQM improvement programs are more likely to successfully implement green supply chain management practices. JIT programs are designed to eliminate all forms of waste, and TQM programs are designed to focus on providing only quality products and services to customers, thereby supporting environmental sustainability and environmental performance while providing a synergistic effect.

Some additional discussion related to the finding of non-support for *H3* (JIT→EVP) is warranted. It should first be noted that, while JIT does not directly impact EVP, JIT does indirectly impact EVP through both GSCMP and TQM. The indirect support through TQM supports similar findings by Zelbst *et al.* (2010, 2014), who found that TQM fully mediated the impact of JIT on measures of organizational performance. JIT was developed prior to TQM and serves as the foundation for the successful implementation of TQM. The implementation of JIT develops efficiency capabilities throughout all process. This efficiency is required before TQM effectiveness capabilities can be fully employed. It is not that JIT does not impact performance but that the impact of JIT is felt through TQM. The finding that JIT indirectly impacts EVP through GSCMP is logical though not previously studied. JIT is focused on the elimination of all forms of waste leading to greater efficiency. GSCMP are focused on the elimination of all forms of environmental wastes. The general capabilities of waste elimination fully support the specific capabilities to eliminate environmental wastes.

6.1 Limitations of the study

While the objectives of the study are accomplished, there are limitations that should be considered when interpreting the results. The sample is limited in that only US manufacturing managers are included. In addition, as with all survey-based studies, there are concerns related to both common method bias and non-response bias. Assessments indicate that the biases do not cause significant problems, however. It has become more and more difficult to attain high response rates in operations and supply chain management survey-based research (De Beuckelaer and Wagner, 2012; Harmon *et al.*, 2002; Larson, 2005). An additional limitation of this study is the relatively low response rate. While the response rate is low, the sample size is sufficiently large to support the PLS-SEM statistical methodology. We believe that the sample is diverse and representative of US manufacturers but understand that the study could be improved with a higher response rate. While our focus was on establishing the relationships among JIT, TQM and green supply chain practices and the combined impact of those practices on environmental performance, it should be noted that it is important to note that other constructs such as culture, industrial sector characteristics, market characteristics may also impact the degree to which the study constructs impact performance.

6.2 Future research

This study extends the work of Zhu and Sarkis (2004) by posing and assessing an alternate model of the relationships among JIT, TQM, green supply chain management practices and environmental performance. Zhu and Sarkis (2004) generated correlations based on analysis of Chinese firms. We verify the positive significant correlations with a US sample.

The results of this study support the proposition that organizations with established JIT and TQM programs should be better able to adopt green practices and improve environmental performance. Vokurka *et al.* (2007) identified three strategic imperatives: low cost, high quality, and responsiveness. Zelbst *et al.* (2010) incorporated those imperatives within a comprehensive model that also included customer focus finding that the imperatives work together synergistically. The work of Zhu *et al.* (2008) and Green *et al.* (2012) identified environmental sustainability as an additional strategic imperative that may be incorporated within the comprehensive model as a means to achieve competitive advantage. We recommend that additional research be undertaken to assess this unified model that incorporates customer focus, low cost, high quality, responsiveness and environmental sustainability. We also recommend that the impact of environmental and organizational constructs such as culture, industrial sector characteristics, market characteristics be incorporated into the study model in future research to assess the impact of such contextual constructs on the ability of JIT, TQM and green supply chain practices to improve environmental performance.

6.3 Implications

Concerning implications for research, this study establishes the complementarity of JIT, TQM and green supply chain practices as they combine to improve environmental sustainability. In addition, the sequencing of the practices is established with JIT emerging as an antecedent to TQM. Researchers should further consider how these three sets of practices combine to impact other forms of performance such as operational performance and organizational performance.

Concerning implications for practice, this study provides practitioners with a constructive case for the implementation of JIT, TQM and green supply chain management practices in combination in support of an environmental sustainability strategy. The positive results associated with JIT and TQM are well established. JIT programs seek to eliminate all forms of waste, reducing the costs associated the production and delivery of goods and services, thereby increasing profits. TQM programs support a customer focus yielding goods and services that meet customer requirements leading to increased sales and market share which also translates into increased profits. Environmental sustainability has been established as a new strategic imperative. Customers want goods and services that are environmentally friendly and are produced and delivered through processes that do not damage the environment. The results of this study suggest that manufacturing managers ensure that JIT and TQM programs are in place and functioning well before attempting to adopt green supply chain management practices. The full impact of green practices may not be realized unless paired with JIT and TQM. As stated by Larson and Greenwood (2004) they are "potentially perfect complements that, effectively linked, hold the potential to vault sustainability forward" and quicken "the pace toward a more sustainable form of capitalism." Finally, Ho (2010) says, "lean [JIT/TQM] is the prime mover and driving force for conserving our environment."

Concerning societal implications, this study offers a managerial approach to improving the environment in pursuit of environmental sustainability. While this study was conducted within the context of the US manufacturing sector which is relatively mature, the findings may be used to provide some general direction to manufactures in other parts of the world. We believe that the implementation of JIT will lead to a more efficient use of resources, the implementation of TQM will lead to increased effectiveness in that customers receive quality goods and services that they desire, and that the implementation of green supply chain practices will extend such efficiency and effectiveness across supply chains from suppliers' suppliers to ultimate customers. Such extensions of efficiency and effectiveness support the societal imperative of environmental sustainability.

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Appendix. Measurement scales

Unique JIT management practices (Flynn *et al.*, 1995)

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

Kanban

(1) Vendors fill our kanban containers, rather than filing purchase orders.

(2) Our suppliers deliver to us in kanban containers, without the use of separate packaging.

(3) We use kanban pull system for production control.

(4) We use kanban squares, containers or signals for production control.

Lot size reduction practices

(1) We have small lot sizes in our plant.

(2) We tend to have small lot sizes in our master schedule.

(3) We are aggressively working to lower lot sizes in our plant.

Setup time reduction practices

(1) Our crews practice setups to reduce the time required.

(2) We are aggressively working to lower setup times in our plant.

(3) We have low setup times of equipment in our plant.

JIT scheduling

(1) We usually meet the production schedule each day.

(2) There is time in the schedule for machine breakdowns or production stoppages.

(3) Our schedule is designed to allow time for catching up, due to production stoppages for quality problems.

Unique TQM practices (Flynn *et al.*, 1995)
Please indicate the extent to which agree or disagree with each statement (1 = strongly disagree, 7 = strongly agree).

Customer focus

(1) We frequently are in close contact with our customers.

(2) Our customers often visit our plant.

(3) Our customers give us feedback on quality and delivery performance.

Product design

(1) There is considerable involvement of manufacturing and quality people in the early design of products, before they reach the plant.

(2) We design for producibility.

(3) We make an effort, in the design process, to list only the specifications which are clearly needed.

(4) The emphasis in part design is on minimizing the part count.

(5) We are concerned about the number of parts in an end item.

(6) New product designs are thoroughly reviewed before the product is produced and sold.

(7) Manufacturing engineers are involved to a great extent before the introduction of new products.

Statistical process control

(1) A large number of the equipment or processes on the shop floor are currently under statistical process control.

(2) We make extensive use of statistical techniques to reduce variance in processes.

(3) Charts showing defect rates are posted on the shop floor.

Green supply chain management practices (Zhu *et al.*, 2008)
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).

Internal environmental management

(1) Commitment of GSCM from senior managers.

(2) Support for GSCM from mid-level managers.

(3) Cross-functional cooperation for environmental improvements.

(4) Total quality environmental management.

(5) Environmental compliance and auditing programs.

(6) ISO 14001 certification.

(7) Environmental management systems.

Green purchasing

(1) Eco labeling of products.

(2) Cooperation with suppliers for environmental objectives.

(3) Environmental audit of suppliers' internal management.

(4) Suppliers' ISO 14000 certification.

(5) Second-tier supplier environmentally friendly practice evaluation.

(6) Providing design specification to suppliers that include environmental requirements for purchased item.

Cooperation with customers

(1) Cooperation with customers for eco-design.

(2) Cooperation with customers for cleaner production.

(3) Cooperation with customers for green packaging.

(4) Cooperation with customers for using less energy during product transportation.

Eco-design

(1) Design of products for reduced consumption of material/energy.

(2) Design of products for reuse, recycle, recovery of material and/or component parts.

(3) Design of products to avoid or reduce use of hazardous products and/or their manufacturing process.

Investment recovery

(1) Investment recovery (sale) of excess inventories/materials.

(2) Sale of scrap and used materials.

(3) Sale of excess capital equipment.

Environmental performance (Zhu *et al.*, 2008)

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):

(1) Reduction of air emissions.

(2) Reduction of effluent waste.

(3) Reduction of solid wastes.

(4) Decrease in consumption for hazardous/harmful/toxic materials.

(5) Decrease in frequency for environmental accidents.

(6) Improvement in an enterprise's environmental situation.

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