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Is “Lean” Synergistic with Sustainable Supply Chain? An Empirical Investigation from Emerging Economy

Abstract:

The propinquity between leanness and sustainability has been widely explored and argued about in the extant literature. However, the literary discourse on the relationship between lean processes and their impact on sustainable performance of a supply chain is debatable. Some researchers have agreed upon the nature of inter-relationship between ‘lean’ and ‘green’ as synergistic whereas some researchers have termed it as coincidental or even dichotomous. This contentiousness can be attributed to the lack of observing the relationship from a holistic standpoint. Literature abounds in independent examinations of the effect of lean practices on sustainability from the context of specific supply chain aspects such as sourcing, production and distribution. We submit that the inconclusiveness in the relationship between lean and green arises from not investigating it from a holistic standpoint. In this study, we address this gap by adjudging the relationship of lean systems with sourcing, production and logistics from a holistic supply chain context. We examine the relationship in the context of emerging economy such as India. The relationships were tested using structural equation modeling. We find that lean processes positively affect sustainable sourcing and sustainable production processes whereas they are negatively associated with sustainable logistics.

Keywords: Lean, Green, Sustainable Supply Chain, Emerging Economy

1. Introduction

Industrial sector, all around the world, has borne witness to the panoply of process management practices that have been adopted in order to restore operational efficiency in the firm and ensure its claim in the competitive market. Firms have seen the transition from the, yesteryear practices like business process re-engineering, six sigma and TQM to the more recent practices like ERP systems, data mining, lean six sigma and "Lean start-ups" (Benner & Tushman, 2015). The transformation in the nature of these practices is necessitated by the changing needs of the markets, customers and society. In the emerging economies alone there has been rapid growth of about 671% by 1970 onwards (Drake & Spinler, 2013). This exponential demand has fired up the economic and industrial activity, and as a consequence, it has proliferated manifolds. However, this revved-up industrial activity at the current levels of technology is, purportedly, not ecologically sustainable (Sarkis & Zhu, 2018). A news report suggests that if emerging economies alone, start consuming at the rate of United States, we would need an extra of four 'planet earths' to satiate our requirements and needs (McDonald, 2015). Moreover, industrial growth has resulted in an endless series of hazardous ecological ramifications like smog, acid rain, global warming and loss of biodiversity all across the world (Sarkis & Zhu, 2018), the costs of which have been, invariably, borne by the 'people'. In the wake of these developments, two phenomena have occurred; first, the consumers have started demanding greener products and services and second, resource efficiency in economic activity has gained immense amount of importance (Groening et al. 2018). They have increasingly been perceived as the pivotal drivers of sustainability and long term corporate health (Ba et al., 2013). In an attempt to address the adverse environmental implications of the economic activity and at the same time enhancing its economic viability, researchers have started exploring 'lean practices' and their impact on sustainability (Zhu et al., 2018). ‘Lean’ is a philosophy built around ‘waste minimization’. It is administered by imbibing a ‘bundle of practices’ which aim endlessly to achieve higher levels of resource efficiency in the system and try to culminate any non-value added activities (Carvalho et al., 2011; Netland & Ferdows, 2016). Various researchers have explored lean practices and their impact on the sustainable performance of a firm. Literature abounds with contradictory findings of whether lean practices abet and abut the sustainable foundations of a firm (or) they inhibit and impede a firm’s sustainable performance. For instance, the likes of King & Lenox (2001) and Dües et al. (2013) propounded that lean practices and sustainable performance of a firm are two sides of the same coin whereas Biggs (2009) and Angell (2001) attributed these mutual gains to serendipity. In their seminal paper, Zhu and Sarkis (2004) also warned that manufacturing organization with Just-in-Time (lean practice) implementation may be in conflict with with internal environmental management practices which leads to degradation in environmental performance. Moreover, all the research on lean practices until now has been focused on the impact of lean systems on standalone aspects of the supply chain such as manufacturing, supplier selection or distribution and logistics. The only study is by Zhu and Sarkis (2004) and they have considered JIT and quality management as moderator of the relationship between GSCM practice and organizational performance. We extend this line of enquiry and propose that it is imperative that the impact of lean practices on sustainability is studied in the context of the whole supply chain and not just in terms of any single aspect of the supply chain. Firms are not only accountable for the environmental damages caused by them but they are also answerable for the activities of their upstream and downstream partners (Rao, 2004). Thus it is pertinent that firms are studied in the light of supply chain management entities rather than standalone business entity. Lean principles are inward-looking and focus on the internal processes of a firm whereas supply chain management encompasses an outward-looking approach which focusses on pan-firm operations and processes (Hajmohammad et. al., 2013). Since their underlying principles are entirely different, it is reasonable that their effects are independent in nature. Their effects could be synchronous or dichotomous. Heretofore there has been no study that explores the impact of lean practices on sustainability from the holistic context of supply chain management. In this study, we attempt to fill this gap by determining the impact of lean systems on sustainability from the purview of all supply chain management functions such as sourcing, manufacturing and distribution. The proposed relationship is explained by Resource based View of the firm. Rest of the paper is outlined as below.

Section 2 discusses relevant literature. Section 3 presents theoretical underpinning and hypotheses development. Proposed methodology is described in section 4. Section 5 presents results and discussion. Finally, conclusion of the study is drawn in section 6.

2. Literature review

Lean practices are founded on the principles of Kaizen, Kanban and JIT (Carvalho et al., 2011). Rothenberg et al. (2001) stratified the aspects of lean systems in the following categories: i) buffer minimization, ii) work systems, and iii) human resource management. Lean systems aim to reduce the ‘slack’ by reducing the wastes of transport, waiting, inventory, motion, over processing, over production and defects. This philosophy subscribes to the implementation of ‘best practices’. Lean systems continually attempt to improve the best practices by making continuous incremental improvisations (Biggs, 2009). These systems focus on meticulous selection procedure of the workforce. They invest in employees training and development as well (Rothenberg et al. 2001). Such systems entail horizontal organizational structures without much power distance. Lean systems see employee motivation and involvement as pivotal drivers of enhanced efficiency (Rothenberg et al. 2001).

Sustainable practices, basically from the environmental perspective are categorized as pollution prevention and pollution control (Rothenberg et al., 2001). Pollution prevention practices are proactive in nature and they attempt to make fundamental changes in the process in order to curtail the environmental damages. These practices also incur sufficient amount of resources in terms of time and money in implementation. Pollution control activities, on the other hand, are reactive in the sense that they attempt to make miniscule changes in the resource structure of the firm and incur minimal costs to implement. They are done to curb the after effects of the already occurred environmental damages (Albertini, 2013). There have also been other ways of analyzing sustainable practices. Etzion (2007) categorizes sustainable practices in environmental design, environmental waste and environmental recycling practices.

Various researchers have also explored the relationship of lean and sustainable systems. The findings in this regard are vexed. For instance, Mollenkopf et al. (2010) propagated that incorporating lean principles into their work culture is complimentary to their environmental performance. King and Lenox (2001) explained the synchronicity by suggesting that lean systems make it easier for firms to identify sustainable improvement opportunities by spreading awareness among employees and enhancing information flow. However, literature has a significant number of apologists who feel that lean systems do not improve sustainable performance of a firm or even if they do, such effect is purely coincidental. For instance, Biggs (2009) posited that any such positive association between lean systems and sustainable firms are purely coincidental. Zhu and Sarkis (2004) found that JIT (which is a major component of lean manufacturing) has negative moderation effects on internal environmental management of Chinese manufacturing firms.

Furthermore, they caution that organizations must be very careful while implementation of green supply chain practices with JIT philosophies in place. Angell (2001) argued that lean systems and sustainable practices have different drivers and motives. Dües et al. (2013) reasoned out by pointing out that unlike sustainable practices, for lean systems, environment is a resource and not a constraint and thus they are bound to differ. Summarily the discourse on the impact of lean systems on sustainable performance is inconclusive.

There exist independent silos of research between lean systems and sustainability from supply chain aspects such as manufacturing, supplier selection and logistics (Simpson & Power, 2005). The major part of research has been done with the manufacturing aspect of the supply chain (Hajmohammad et al., 2013). The reason for such inclination can be attributed to the fact that 'lean' as a philosophy has generated from and for processes only (Ugarte et al., 2016). There is also research regarding supplier selection aspect (Hajmohammad et al., 2013, Bai & Sarkis, 2010; Sarkis & Talluri, 2002). Hajmohammad et al. (2013) state that by implementing lean principles in suppliers, firms can better their environmental performance. For instance, Walmart uses a packaging scorecard to determine the efficiency in packaging of its suppliers. By enhancing the packaging efficiency of its suppliers its ecological footprint is also reduced. Apart from supplier selection, there are studies on the impact of Just-in-time (JIT) and inventory minimization which are crucial aspects of lean systems on sustainable performance of firms. The impact of JIT on sustainable performance in terms of environmental emissions is contentious (Hajmohammad et al., 2013). Ugarte et al. (2016) posit that JIT manufacturing leads to better environmental performance. Tracey et al. (1995) suggest that JIT can be implemented in a way that sustainable performance is bettered but Smith et al. (2005) express their apprehensions about the implementation of JIT to not affect the emissions adversely. The authors suggest that there is a significant link between set-up time reduction and inventory optimization leads to better environmental performance. Galeazzo et al. (2014) also submit that inventory management led to increased total emissions in the supply chain. On the contrary, King and Lenox (2001) found that inventory management lowered the environmental emissions. Such inconclusive findings could be a result of not observing the supply chain aspects from a holistic aspect. Fullerton et al. (2014) suggest that lean principles must be adopted and analysed in an all-encompassing framework of business activities and not just in operations and processes.

3. Theoretical Underpinning and Hypothesis Development

Literature on sustainability is abound with claims of building such core competencies for a firm which are valuable, rare, non-inimitable and non-substitutable which give it a sustained competitive advantage in terms of improved sustainable performance (Barney, 1991). This theoretical standpoint of building core competencies which provided a firm with a sustained competitive advantage is well known as resource based view (RBV) theory. Theorists have moved further from this pivotal school of thought by dwelling on its applications in the context of sustainability, namely, Natural resource based view (NRBV) theory (Hart, 1995) and by incorporating the dynamicity and learning nature of a firm in the form of Dynamic capability (DC) theory (Teece et al., 1997). However, these alterations and repackaging in its form and substance has only added to its acceptability as they demonstrate the wide appeal of its basic premise that in order to build a sustained competitive advantage, it is imperative that a firm builds a set of path-dependent competencies based on its resource structure, knowledge base, processes and technology to earn supernormal rents in its sphere of economic activity (Koufteros et al., 2012; Sarkis et al., 2010). Whether that set of competencies need to change with time (DC theory) or whether that set of competencies is environment-centric (NRBV) is a question that researchers may answer according to their prerogative but the fact that such competencies need be present is indisputable.

Lean systems are steeped in a philosophy of waste minimisation and resource efficiency in an organization's work culture, processes, human resource and strategy. It is a systematic mindset that a firm adopts when it goes 'lean' and its implementation is a continuous process which revolves around continual efforts and continuous improvements (Kaizen). It is path dependent process in the sense that it takes its own course of time for a firm to become lean. It cannot be duplicated by any other firm as its implementation is quite idiosyncratic, and thus is non-imitable. The fact that the core tenet of lean practices is waste minimization and resource efficiency, it is imperative that their impact is measurable in terms of tangible economic returns. Thus, they are valuable. And in the world of ever shrinking profits and ever shortening product lifecycles with ever more competitors to compete with, the standpoint that the business activity is run on minimal resources and disposes minimal waste is indispensable. In such competitive environment, 'lean' philosophy is non-substitutable. It can be appended with others but most positively can't be scraped off altogether. We observe that lean practices have all the elements worthy of becoming a core competency not only for a firm but for the entire supply chain. Heretofore, lean processes have been studied independently in connection with various supply chain aspects such as sourcing, manufacturing and logistics (Simpson & Power, 2005). We submit that the impact of lean processes on sustainable performance should be gauged in its entirety by taking all the supply chain functions together.

Regarding sustainable supplier selection, literature has unanimously cited results which suggest that lean processes are synergistic with sustainable supplier selection. Hajmohammad et al. (2013) cite the case of Walmart that by using packaging scorecards it revs up the ecological efficiency of its suppliers and reduces its own ecological footprint. Lewis (2000) accounted for "supplier involvements" in designing new products and processes which formed essential components of lean production. Thus, we hypothesize that,

H1: Lean practices are positively associated with sustainable supplier selection.

With regard to manufacturing and production, lean processes are tailor made for this aspect of supply chain (Ugarte et al., 2016). The pivotal study of King and Lenox (2001) propounded that lean processes are complimentary to better environmental performance in production. They suggested that lean practices lowered the cost of pollution abatement. Rothenberg et al. (2001) also substantiated the positive synergy between lean production and better sustainable performance. Thus, we hypothesize that,

H2: Lean practices are positively related with sustainable production.

Distribution and logistics have been a contentious issue. Ugarte et al. (2016) concluded that lean distribution of fast moving and consumable goods resulted in elevated emission levels in the logistic functions. McKinnon and Woodburn (1994) and Kohn and Huge-Brodin (2008), take a contrarian view and argue that green-house gas emission from distribution and logistics can be substantially reduced by centrally planning and consolidation of freight flows. Whereas, Smith et al. (2005) asserted that minimizing the consolidated travel distance need not reduce the environmental footprint if measured on life cycle analysis based approach. We observe that the inconclusive findings could have to do with the scope of assessment as such and we concur with the findings of Smith et al. (2005) that, even if, consolidation results in reduction of firm-centric freight emissions but it may not necessarily result in any reduction when seen from a life cycle viewpoint. That is, just-in-time and inventory minimization will invariably lead to increased and frequent replenishment cycles and thus increased overall distance travel. Thus, we hypothesize that

H3: Lean practices are negatively associated with sustainable delivery and logistics.

4. Methodology

The proposed hypothesized relationship is shown in figure 1. In this study we used original survey data from Indian manufacturing organizations. We used Structural Equation Modelling approach to test the proposed hypotheses.

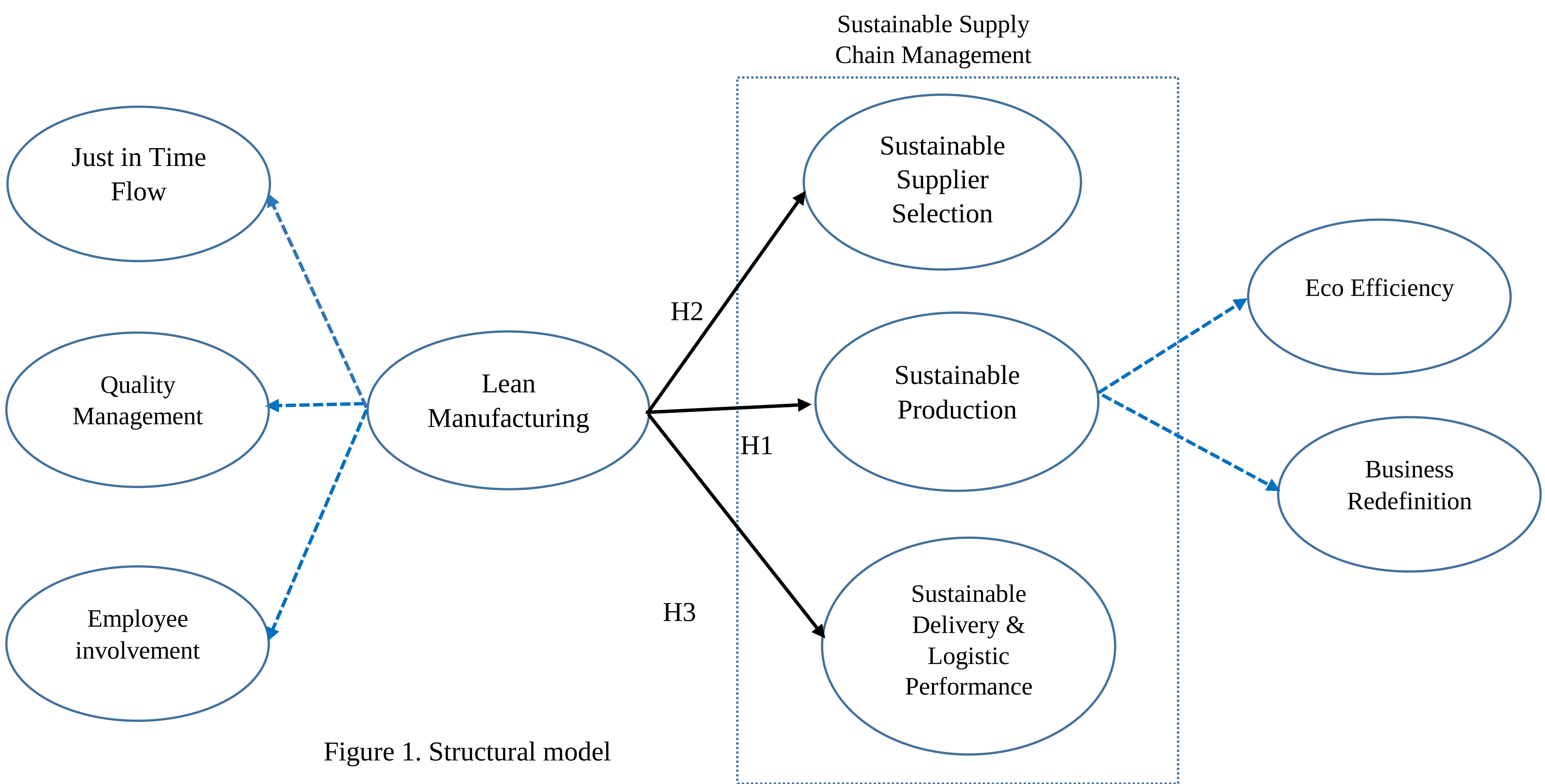

Figure 1. Structural model

4.1Survey Instrument

To develop a scale to measure construct of interest namely: Lean Management and consideration of sustainability aspects of three important supply chain echelons (Supplier Selection, Manufacturing and delivery & logistics services) we first analyzed the extant literature. After careful comparative analysis, we choose reliable and valid scale of Yang et al. (2011) for Lean management. However, we modified this scale in consultation with expert panel (Table 1). To measure sustainability practices of three supply chain echelons, we analyzed the key paper and collected a pool of items (Bai & Sarkis, 2010; Kusi-Sarpong et al, 2016; Sarkis et al., 2010, 2011; Zhu et al., 2005, 2008 and many more). Few new items were also added to tap the Indian context. Finally, we also conducted a pretest by having an expert jury composed of 12 senior supply chain executives, 5 academicians working in sustainability area and 3 senior government official working in environmental ministry. The panel members were asked to appraise the measurement scale on following two aspects: (1) Ease with which they are able to comprehend it (2) whether it measure what it intended to. This exercise also ensured construct validity of measurement scale. The final scale is given in Table 1 & 2.

4.2. Survey design and sample

We designed a survey instrument to collect information about the implementation level of Lean Management practices along with consideration of sustainability criteria in supplier selection, manufacturing and delivery & logistics services in Indian manufacturing organizations. The unit of analysis is chosen as an individual manufacturing unit as the implementation of Lean practices is ultimately done at individual manufacturing facility level only. Moreover, the decision related to supplier selection and delivery & logistic service provider selection depends on numerous factors such as location of the facility, supply market, domestic or export oriented unit etc.

Therefore, we believed individual manufacturing unit would be an ideal unit of analysis. With respect to choice of respondent at individual manufacturing unit, individual working in the capacity of supply chain management at middle to senior managerial cadre would be the ideal respondent of our survey.

Table 1. Measurement Scale for Lean Management. Source: Yang et al. (2011) with modification

Please indicate the implementation/consideration status of below given sustainability practices at your manufacturing facility. {1 Not considered, 2 For future consideration, 3 Planning to consider, 4 Currently considering, 5 Successfully implemented }

Construct	Definition	Items
Just in Time Flow	It is continuous process improvement approach to remove waste and where raw material, work in process and finished goods are pulled by next stage at right time in right quality and quantity.	JIT1 In order to achieve continuous product flow, processes and layout are redesigned JIT2 Bottlenecks and buffers are removed, Kanban is implemented
Quality Management	Designing the process and methods for zero defects and worker driven continuous improvement.	QM1 Worker driven continuous improvement (Lean six sigma, quality circle etc) QM2 Quality is built in design and methods such as Mistake Proofing (poke yoke)
Employee Involvement	“Respect for Human” system with open and honest communication where the workers are encouraged to report mistakes and improvement suggestions.	EI1 Suggestions per employee as compared to others in industry EI2 Training Hrs of New Production Workers EI3 Importance to open and honest communication EI4 Workers are empowered to stop assembly line if observed any mistake

As the survey instrument included the aspects of lean management, supplier selection and delivery & logistics service provider selection which span across the various function as well as upstream and downstream entities of manufacturing organization, supply chain manager is an individual must be dealing with all these aspects. Moreover, we requested the chief of human resource management of a unit to provide detail of a business manager involved cross functional decision making and aware about environmental issues. The manufacturing facilities with more than 100 employees and operational for more than 10 year chosen as study sample. This condition ensured that choosen facilities had completed at least a couple lean projects. Moreover, sustainability management ideas may not apply to small start-ups in their initial phases. For building a sample, we generated a list of 1478 manufacturing facilities satisfying above given sample selection criteria from CMIE[1] Prowess database. Three methods were used to collect the survey responses as: 1. Web based survey with self-administered electronic set of questions on the Web (web link of the survey sent through an email). 2. Sending the printed questions with choice of tick mark at the chosen responses through mail with returned envelop. 3. A field visit with prior appointment. In order to enhance response rate, the respondents were asked to choose among above mentioned three options through an initial email followed by a telephone reminder after a week. A total of 297 responses were received. Out of which, 12 were discarded as they were incomplete. The final list of 285 responses comprises 132 collected using web based survey, 67 collected using mail, and 86 collected using field visits. Description of the sample is given in Table 3. To check whether non-response bias may be an issue or not, we compared the 285 respondent firm with randomly selected nonresponding firms on various dimensions such as sales, ROA and industry type (differentiating by 2 digits sic code) using *T*-test. Chi-Square test of independence were also used to compare the different survey methods. No significant difference was found. We were also concerned with the fact that in the final data, the representation from different manufacturing industry were not equal.

[1] Centre for Monitoring Indian Economy

Table 2. Measurement Scale for Sustainable Supply Chain Management Please indicate the consideration of following criteria regarding selection of supplier {1 Indicates Unimportant, 2 Little Unimportant, 3 Neutral, 4 Little Important, 5 Very Important}		
Construct	Definition	Items
Sustainable Supplier Selection Source: Kusi-Sarpong et al., 2015	Selection of suppliers on the basis of standard environmental criteria along with quality and price considerations.	SSS1 Jointly develop environmental management solutions SSS2 Regular audits for environmental compliance and practices of supplier's operations SSS3 Combined teams to reduce material use and reuse recycled materials
Sustainable Production Please indicate the implementation/consideration status of below given sustainability practices at your manufacturing facility. {1 Not considered, 2 For future consideration, 3 Planning to consider, 4 Currently considering, 5 Successfully implemented }		
Eco Efficiency	The sustainable practices which considers all sorts of pollution as a manifestation of inefficient usage of resources and controlling wastes and emissions is a step towards enhancing efficiency.	EE1 Environmental compliance and auditing programme (such as ISO 14001) EE2 Reduce material & energy use EE3 Detoxification of water and air
Business Redefinition	The sustainable practices which brings fundamental design changes in their products and processes.	BR1 Designing product for easy disassemble or reuse BR2 Introduction innovative products with sustainability consideration BR3 Strive to develop sustainable technology
Measurement Scale for Sustainable Supply Chain Management Please indicate the consideration of following criteria regarding selection of delivery & logistic service provider. {1 Unimportant, 2 Little Unimportant, 3 Neutral, 4 Little Important, 5 Very Important}		
Sustainable Delivery & Logistic Performance	Consideration of sustainability criteria while designing the distribution system	SDL1 Environmental consideration while selecting mode of transport SDL2 Preference to new & more fuel-efficient vehicles SDL3 Consolidation of freight flow to reduce environmental impact

This may skew the findings and generalizability may be questioned. We used analysis of variance to test whether there is significant differences among responses received from different industries and no statistically significant difference was found ($F = 0.02$). The result of above analysis provided us reasonable confidence for the representativeness of our survey data.

Table 3. Description of the study sample

2 Digit SIC Code	Description	Number of responses	Percentage
20	Food & Kindred Products	6	2.1
21	Tobacco Products	11	3.9
22	Textile Mill Products	21	7.4
23	Apparel & Other Textile Products	25	8.8
24	Lumber & Wood Products	12	4.2
25	Furniture & Fixtures	20	7
26	Paper & Allied Products	13	4.6
27	Printing & Publishing	17	6
28	Chemical & Allied Products	9	3.2
29	Petroleum & Coal Products	12	4.2
30	Rubber & Miscellaneous Plastics Products	9	3.2
31	Leather & Leather Products	12	4.2
32	Stone, Clay, & Glass Products	14	4.9
33	Primary Metal Industries	19	6.7
34	Fabricated Metal Products	14	4.9
35	Industrial Machinery & Equipment	17	6
36	Electronic & Other Electric Equipment	19	6.7
37	Transportation Equipment	10	3.5
38	Instruments & Related Products	11	3.9
39	Miscellaneous Manufacturing Industries	14	4.9
Total Responses		285	100

Since the data were collected from single respondent for every manufacturing facility, common method variance may be a serious concern. Harmon's single factor test, where all the variables were entered and unrotated factor score were obtained (Podsakoff et al., 2003). No single factor could explain the covariance among measure which signify that common method bias is a not a very significant issue.

4.3 Measurement Model

In this study, we measure seven constructs from 20 items. We examined various measure of reliability and validity measurement scale. Table 4 provides brief definition and guidelines for the tests.

Table 4. Measurement Model Tests		
Test	Definition	Guideline
Item reliability	variance of a measurement variable explained by its construct vis a vis variance due to error in measurement (Fornell & Larcker, 1981).	It should be statistically significant.
Internal consistency	How well the items measuring the underlying construct.	Cronbach alpha reliability coefficient ≥ 0.7; $\rho c \geq 0.7$; $AVE \geq 0.7$. Composite reliability (ρc) = $[(\Sigma \text{ standardized loading})^2 / [(\Sigma \text{ standardized loading})^2 + \Sigma \epsilon_j]$, where ϵ_j is the measurement error. Average variance extracted (AVE) = $\Sigma (\text{standardized loading}^2) / [\Sigma (\text{standardized loading}^2) + \Sigma \epsilon_j]$.
Discriminant validity	Degree to which conceptually similar concepts are distinct	AVE of construct$\geq$ squared correlation between constructs.

The item reliability value ranged from 0.59 to 0.83 (as given in table 5) and all are statistically significant ($p < 0.01$) which establishes item reliability. The Cronbach alpha value also found to be greater than threshold 0.7 (Table 6) for all latent constructs. We also calculated the composed reliability by using the formula given in Table 4. All the ρc value indicates that measurement scale demonstrate adequate internal consistency. Finally, Average variance extracted (AVE) were also determined to see whether they exceed the threshold value 0.5 or not. The calculation in Table 6 also shows that variance captured by construct is very high as compared to variance due to error in measurement and establishes the convergent validity of the

Table 5. Results of Measurement Model					
Items underlying the construct	Unstandardized path coefficient	Standard error	Critical ratio	Standardised path coefficient *	Item reliability
Just in Time Flow (JIT)					
JIT1	1.00	fixed		0.91	0.83
JIT2	1.87	0.29	10.61	0.83	0.69
Quality Management (QM)					
QM1	1.00	fixed		0.87	0.76
QM2	1.93	0.29	13.92	0.89	0.79
Employee Involvement (EI)					
EI1	1.00	fixed		0.85	0.72
EI2	1.98	0.19	13.64	0.83	0.69
EI3	2.08	0.21	12.61	0.89	0.79
EI4	2.36	0.28	9.87	0.91	0.83
Sustainable Supplier Selection (SSS)					
SSS1	1.00	fixed		0.88	0.77
SSS2	1.96	0.31	10.34	0.82	0.67
SSS3	1.78	0.26	11.87	0.86	0.74
Eco Efficiency (EE)					
EE1	1.00	fixed		0.84	0.71
EE2	1.68	0.18	13.57	0.89	0.79
EE3	1.79	0.23	10.46	0.79	0.62
Business Redefinition (BR)					
BR1	1.00	fixed		0.84	0.71
BR2	1.61	0.22	11.30	0.86	0.74
BR3	1.72	0.27	9.42	0.80	0.64
Sustainable Delivery & Logistic Performance (SDL)					
SDL1	1.00	fixed		0.77	0.59
SDL2	1.68	0.07	14.59	0.82	0.67
SDL3	1.73	0.16	13.85	0.80	0.64
* Statistically significant at p<0.01.					

scale (Fornell & Larcker, 1981). Correlation coefficient between construct is given in Table 7 with diagonal elements shows squared root of construct's AVE. As can be seen from Table 7 the diagonal elements are significantly higher than rest elements in every column. The parsimonious representation of construct of the study were developed using the exploratory factor analysis by using the principle component method. The items we planned *ex ante* to represent a separate construct. The items which having loading more than 0.4 on more than one construct were deleted.

Table 6. Psychometric property of first order measurement scales.

S.No	Latent Variables	Mean	Variance	Number of items	Cronbach's alpha	Composite reliability	Average variance extracted
1	Just in Time Flow	0.25	0.04	2	0.73	0.85	0.65
2	Quality Management	0.21	0.06	2	0.77	0.87	0.68
3	Employee Involvement	0.36	0.03	4	0.93	0.94	0.73
4	Sustainable Supplier Selection	0.38	0.01	3	0.83	0.90	0.74
5	Eco Efficiency	0.28	0.03	3	0.79	0.86	0.77
6	Business Redefinition	0.31	0.01	3	0.81	0.87	0.62
7	Sustainable Delivery & Logistic Performance	0.23	0.03	3	0.88	0.91	0.71

Then performed confirmatory factor analysis to verify the initial results. The factors accounted more than 72% variance in the data with eigenvalue greater than 1.

Table 7 Correlations between latent variables (square root of average variance extracted in the diagonal)

Latent Variables	1	2	3	4	5	6	7
1	**0.85**						
2	0.45**	**0.86**					
3	0.31*	0.55**	**0.82**				
4	0.07	0.37**	0.41**	**0.88**			
5	0.19	0.58**	-0.27*	0.26*	**0.84**		
6	0.16	-0.24*	-0.19	0.26*	0.30*	**0.79**	
7	0.29*	-0.23*	-0.42**	0.11	0.15	0.23*	**0.85**

1. Just in Time Flow 2. Quality Management 3. Employee Involvement 4. Sustainable Supplier Selection 5. Eco Efficiency 6. Business Redefinition 7. Sustainable Delivery & Logistic Performance * $p<0.05$ (2-tailed); ** $p<0.01$ (2-tailed)

Having established the reliability and validity of measurement scale, below we estimate the hypothesized relationship.

4.4 Structural Model

The structural model is shown in figure 1. The data were analyzed using the statistical package AMOS 20 by using the maximum likelihood estimation method. In order to access overall model fit, various goodness-of-fit measures were considered. In this paper we considered a mix of absolute, parsimonious & noncentrality-based fit indices. Table 8 shows estimated and recommended fit indices. The result indicates a good structural model fit.

Table 8 Summary of model fit indices for structural mode.

	Chi-square (χ^2)	Degrees of freedom (df)	χ^2/df	GFI	RMSEA	CFI	IFI
Model	1157	588	1.97	0.93	0.048	0.92	9.93
Recommended	---	----	<3 (Sarkis et al., 2010)	>0.8 (Dawes et al., 1998)	<0.10 (Hair et al., 2006)	>0.9 (Hair et al., 2006)	>0.9 (Hair et al., 2006)

Chi-square value is statistically insignificant (p>0.05), which establishes that observed covariance matrix and estimated covariance matrix are in coherence with each other.

5. Results & Discussion

The relationship between lean management and sustainable supplier selection (Table 9) is positive and statistically significant ($\beta = 0.38$, $p<0.01$). Likewise, the relationship between lean management and sustainable production is also positive and statistically significant ($\beta = 0.56$, $p<0.01$). This indicates that adoption of lean management practices positively influence sustainability practices adoption for supplier selection as well as production. However, lean management negatively impact the adoption of sustainability criteria in delivery & logistic service provider selection ($\beta = -0.41$, $p<0.01$). This means that the environmental impact at the supplier and in manufacturing is reduced but the environmental cost in transportation and logistics is increased. In order to analyze the net balance (as positive for two stages but negative for transportation & logistics) we also calculated percentage change values which are shown in the following table.

Table 9. Structural model paths

Antecedent variable	Consequent variable	Unstandardized weight	Standard error	Critical ratio	p value	Standardized regression weight	% change*
Lean Management	Sustainable Supplier Selection	0.38	0.21	5.12	***	0.28	24.5
Lean Management	Sustainable Production	0.56	0.12	5.81	***	0.42	41.5
Lean Management	Sustainable Delivery & Logistic Performance	-0.41	0.14	-5.01	***	-0.31	-30.0

***p<0.01.
* This calculation is performed to indicate percentage change in dependent variable vis-à-vis one unit change is independent variable. Detailed calculation is explained in discussion section.

Based on the unstandardized regression coefficients (Table 9), a unit change in the five-point Likert scale of Lean Practices' impact on facility-level environmental decisions is associated with a 24.5% increase in adoption of sustainable supplier selection practices on average at each facility. The unstandardized regression coefficients represent the resultant change on the consequent variable vis-à-vis unit change in independent variable. Standardization of five point Likert scale between 0 and 1 represents one-point change in scale equivalents to 0.2 as the Likert scale points are equally spaced. The impact of Lean management on sustainable supplier selection is equals to: 0.2×0.38 (Mean value of sustainable supplier selection Table 6) = 0.076, which is 28.1 % of the mean value of the lean management (0.27, average of 3 construct of lean management from Table 6). In a similar vein, we have calculated the impact of lean management on sustainable production and sustainable delivery and logistic practices.

Although the overall impact of lean management on sustainable supply chain practices may be positive, however the negative impact on delivery and logistic practices is a matter of concern. Manufacturing organizations really needs to analyze this tradeoff situation and find a way to reduce its environmental impact without transferring its burden to delivery and logistics. Here our finding echoes with the concern expressed by Biggs (2009) and Zhu & Sarkis (2004). We also propose that the relationship between lean management and sustainable supply chain management is not straightforward. Gain at some place may cause loss at other places. Therefore, the net impact must be seen in totality and segmented analysis may result in inconclusive findings. The contentiousness in the findings may be due to the reason that we tried to solve this puzzle in pieces. A holistic approach is needed to have a synergy between implementation of lean management and sustainability performance of overall supply chain failing to do so would result in zero sum game between different stages of the supply chain.

6. Conclusions

The United States Environmental Protection Agency (EPA) described Lean and Green as “parallel universes of waste reduction”. To date, there is little empirical research on whether lean transcends beyond the notion of environment improvement is a byproduct of the lean which aim to minimize waste to enhance economic efficiency. Moreover, most of the empirical research is conducted at one stage of supply chain such as: lean management and environmental performance of manufacturing facility (mostly), lean management and environmental performance of supplier or logistics service provider (very few).

In this paper we tried to analyze the relationship between lean management and sustainable supply chain management. Theoretically, the proposed relationship is underpinned in the Resource Based View. Lean was considered as second order construct estimated by three constructs namely just-in-Time, quality management and employee involvement. A three echelon supply chain is considered as:

Sustainable Supplier → Sustainable Production → Sustainable Delivery & Logistic

Primary survey data from 285 Indian manufacturing facilities we obtained. The survey was intended to measure the extent of implementation of lean management and consideration of sustainability criteria at the three echelons of supply chain. Results obtained using structural equation modelling method indicates that lean implementation positively influences the implementation of sustainability practices for supplier selection and production but negatively impacts sustainability practices for delivery and logistic services. The reason could be the frequent deliveries with smaller lot sizes a result of inventory minimization. This may lead to less than truckload deliveries more frequently. Moreover, the buffer inventory reduces substantially at different stage to make value flow continuously. In case of exigencies (high demand, disruptions etc.) organizations may be required to use fast mode of transportation with higher emissions. Based on the finding of this study we suspect that reducing lot sizes beyond a certain limit or reducing inventory level (raw material, work in process, finished goods) aggressively may add little value in terms of economic and environmental performance of the manufacturer but may hamper environmental performance of delivery & logistic services extensively. Hence, we submit that business organization must consider overall impact and have an entire system wide view of implementation of lean management.

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