Enabling of Sustainable Supply Chain Management with Lean Thinking – A Study on Manufacturing Firms in Kyoto Protocol Signatories

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ABSTRACT

The research formulates a sustainable supply chain management (SSCM) strategy for manufacturers by showing the potential of lean thinking that lead corporate sustainability to success. A study of the adoption of sustainability was conducted with 527 manufacturing firms in 17 Kyoto Protocol signatories that were practicing lean production. A research model and 4 hypotheses are proposed to create a link between lean and sustainable supply chains. We theorized that manufacturers embrace lean as a pro-environmental practice with a cross-organizational commitment in an electronically-enabled supply chain environment hold promise for adopting SSCM. The results imply that manufacturers in developing countries may consider going lean first in consideration of humanistic values before moving towards adopting sustainability for a better chance of success.

Keywords: e-business, 'green' policy, lean production, supply chain management, sustainability

INTRODUCTION

The Kyoto Protocol, an international agreement linked to the United Nations Framework Convention on Climate Change (UNFCCC), set out the binding targets for over 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions (Hoffman & Woody, 2008). Kyoto Protocol was entered into force on 16 February 2005 with not less than 55 Annex I parties which accounted in total for at least 55 % of total CO\textsubscript{2} emissions, have placed their instruments of ratification, acceptance, approval or accession over the compliance period until 2012 (United Nations, 1998; UNFCCC, 2012). There are 3 groups of Kyoto Protocol signatories according to differing commitments: (a) Annex I parties, i.e. highly industrialized countries and countries with economies in transition (EIT), committed to emission reductions; (b) Annex II parties include OECD members of Annex I. They are required to provide financial support to enable developing countries to undertake emissions reduction activities; and (c) Non-Annex I parties are mostly developing countries with no emission reduction targets such as China and Brazil.

New government regulations in Annex II parties that come into force in response to the Kyoto Protocol will alter key aspects of business strategy of most companies, including production economics, cost competitiveness, investment decisions, and the value of different kinds of assets (Enkvist et al., 2007). The changes will influence various core supply chain activities, such as supplier management, raw material procurement, shipping and transportation costing and the ultimate pricing of goods and
services (Hoffman & Woody, 2008; Cameron, 2001). The experience of companies in Annex II countries on pursuing sustainability is important to followers, i.e. companies in Non-Annex I countries. The study aims to provide manufacturers in Non-Annex I parties with insight of adopting sustainability with reference to the experiences of Annex II parties. In order to formulate relevant sustainable supply chain management (SSCM) strategy, this research attempts to identify and explain the circumstances of applying relevant sustainability principles to manufacturers as business innovations based on Rogers’ Innovation Diffusion Theory (IDT) (Rogers, 2003) through examining various influential factors of adopting sustainability in the supply chain by answering two research questions:

RQ1: What are the factors that cause manufacturers in developed countries to adopt sustainability in light of lean thinking as an operations practice?

RQ2: How do these factors affect the adoption of SSCM?

In the forthcoming sections, a theoretical model and 3 hypotheses are developed and tested based on the survey data from 527 manufacturing firms in 17 Kyoto Protocol Annex II countries. The study shows the potential of lean thinking in SSCM by helping business move away from existing wasteful habits.

BACKGROUND

Sustainability in the context of lean organization

Sustainability constitutes of environmental, social and economic dimensions in which waste management is one of the major challenges to business in strategy formulation (United Nations, 2005). Lean thinking helps eliminate waste and streamline overly complex and nonintegrated processes that result in improved productivity, reduced costs and environmental friendly operations leading to organizational sustainability (Olson, 2008; Womack & Jones, 2003). Lean thinking, which aims for a total management system works for any type of business and shares the same roots with ‘Just-in-time (JIT) manufacturing’ (Womack & Jones, 2003). JIT originates from ‘Toyota production system (TPS)’, a manufacturing management philosophy developed by Toyota, in 1960s (Ohno, 1988). Buker (1991) defines three focus areas for systematically adopting JIT in manufacturing firms with emphasis on organizational development, which results in improved operations and creates humanistic values:

(1) **Systems management** – addresses the effective distribution of parts and materials and proper use of limited resources which may involve restructuring supply strategy such as forming partnership or network with suppliers and establishing pull production systems such that parts and materials can be produced on demand with very short lead times.

(2) **Process management** – involves improvement on existing manufacturing processes through
streamlining, reorganizing or restructuring the layout and set-up, e.g. using cellular layout, or information technology so that waste can be reduced and response time can be minimized.

(3) *People management* – focuses on the development of human capitals to support the continuous improvement objective in JIT through creating proper work environment for employees from president to hourly workers towards this objective. This includes empowerment and training of workforce or establishing autonomous team.

As such, lean thinking can be a business practice for a company aiming to be a sustainable enterprise through continuous improvement of key organizational processes (*kaizen* in its original Japanese name), including not only value chain processes of a company, but also supply chain activities contributing to its supply chain partners’ business effectiveness (Lefevre & Suder, 2009; Ohno, 1988; Wirtenberg et al., 2008; Womack & Jones, 2003). Supply chain activities, which can be organized into five primary processes: *Plan, Source, Make, Deliver, and Return* (Supply Chain Council, 2008), are therefore encountered in reducing emissions. Beside identifying the casual relationships between sustainability and existing business practice, it is necessary to consider current Supply Chain Management (SCM) processes in realizing sustainability, as firms have different value objectives and unaligned operation processes, even if they are trading partners (So & Sun, 2010; 2011).

**Lean thinking enabling supply chain sustainability**

Sustainable enterprises look for systematic way of eliminating energy and other environmental wastes, cutting unnecessary materials and regulatory overheads, all of which are even more important at a time of economic downturn. However, adopting new practices may affect various aspects of SCM processes such as supply policies, manufacturing operations, inventory management, and distribution (So & Sun, 2010; 2011). Extending lean thinking from manufacturing to SCM can leverage a supply chain’s competitiveness with increased responsiveness to demand change and reduced operating costs (Oliver et al., 1993; Ryan, 2001). Leaning thinking helps ramp-up and implement the enhanced SCM processes from product launch to marketing and sales, manufacturing and distribution, and customer service that enables ultimate SSCM adoption by aligning these ‘leaned’ intra-organizational activities with five key SCM processes (Bamford & Forrester, 2010; Fiksel, 2009; Supply Chain Council, 2008).

According to Womack and Jones (2003), the continuous improvement process of lean thinking (i.e. *kaizen*) is a cyclical route to seek perfection by eliminating waste and enriching customer values, which can be achieved by adopting the following four-steps that links customers in the downstream supply chain to suppliers in the upstream supply chain in order to address customer demands appropriately:

1. **Specify value** – (a) customer values which may include: price, delivery speed and service level, and (b) shareholder/management values which may include: reducing cost and inventory level
or acquiring new knowledge/skill;

(2) Identify value stream – The whole sequence of process steps in the supply chain with all the activities, no matter whether they are value adding and non-value adding, should be identified;

(3) Make value flow in the supply chain – Wasteful tasks/processes are removed by lean principles;

(4) Enable customer pull – By working collaboratively with suppliers to make only on response to customer demands, which is essentially a customer demand-driven pull system

With this concept in mind, So and Sun (2010; 2011) studied the adoption of lean thinking in an electronically-enabled supply chain (ESC) environment. The research reveals that lean regularization and organizational integration are key drivers. Wirtenberg et al. (2008) suggested the influential factors that affect sustainability adoption, in which organizational integration is top most important. Harris (2013) argued that information sharing and internal lean practices are critical to the success of SSCM adoption. Sustainability is still relatively early in its adoption cycle. As a result, an operations strategy is required to help facilitate the adoption of SSCM by incorporating above concepts where information sharing, lean practices and organizational integration are postulated to conceptualize SSCM.

RESEARCH MODEL AND HYPOTHESES

The research model is depicted in Figure 1. It studied the effect of lean operations on the commitment to SSCM with the manufacturers’ focus on quality (design, customer service and environment) and product innovation. In order to improve the decision process of SSCM adoption, a two-stage approach based on IDT (2003) is used to frame the SSCM model (Model 1) with the antecedents derived based on literature review:

(1) Implementation (i.e. regularization, putting sustainability in use)

(2) Confirmation (recognizing the benefits of sustainability and promising on-going commitment to it).

The model posits that the decision of adopting SSCM is influenced by its regularization in operations (Model 1) and lean thinking as sustainable organizational practices (Model 2), which are expressed in the following equations where the Greek letter δ is used to designate noise, i.e. the combined effect of excluded independent variables (Jöreskog, and Sörbom, 1993):

Model 1: \[ \text{SSCM Commitment} = f_I (\text{SSCM Regularization}) + \delta \]
Model 2: \[ \text{SSCM Regularization} = f^2 (\text{Lean Organization with Sustainable Objectives, Organizational Integration through Pro-environmental Systems}) + \delta^2 \]

Four hypotheses are developed:

**Lean as a sustainable organizational practice**

*Lean organization with sustainable objectives*

Originated in manufacturing, JIT, a production management philosophy aims to eliminate waste and improve production in a continuous approach such as having only the required inventory when needed, reduction of lead times by reducing setup times, queue lengths, and lot sizes such that these activities are accomplished at minimum cost, and it encompasses the successful execution of all manufacturing activities required to produce a final product, from design, engineering to delivery, and includes all stages of conversion from raw material onward (Cox & Blackstone, 2002). Considering the ability to do more with less, the lean principles behind JIT is used for creating environmental friendly operations (Bozarth et al., 2009). To develop a sustainable enterprise strategy, lean thinking can be adopted as business practice of a company by focusing on value creation and continuous improvement on key organizational processes, which can be applied to not only value chain processes that involve primary and secondary activities of the company, but also major supply chain activities contributing to business effectiveness (Buker, 1991; Womack and Jones, 2003). Furthermore, So and Sun (2010; 2011) argued that manufacturers adopting lean thinking as sustainable practices in their ESCs has positive influence on its regularization in operations. Thus, **H1** is hypothesized as:

**H1**: *Lean organization with sustainability objectives has positive influence on SSCM regularization*

*Organizational integration through pro-environmental systems*

The success of lean thinking in production management demands a high degree of integration of manufacturers’ internal organizational processes including all the classic business functions, such as accounting, finance, purchasing, sales and operations as well as production activities such as material management and production planning and control (Bozarth et al., 2009; So & Sun, 2010; 2011). Pro-environmental systems in this study include enterprise resources planning (ERP) systems and environmental management systems. ERP systems are designed to pull together all of these functions and activities into a single, tightly integrated package through a common database to facilitate end-to-end *information sharing*. Environmental management systems (Darnall et al., 2008) help organisations embed environmental practices deep within their operations so that protecting natural environment becomes an integral element of their overall business strategy. It helps decisions makers understand energy’s role and the consumption pattern in operations across procurement, production and distribution. With pro-environmental systems, lean thinking is supported more effectively (Bozarth et
al., 2009). Cagliano et al. (2006) argued that a lean organization is strongly associated with information sharing among various internal production processes to help not only improve work performance in an ESC environment but also align and streamline business processes to achieve long-term sustainability. Hence, we hypothesized H2 as:

**H2a:** Organizational integration through pro-environmental systems has positive influence on SSCM regularization

**H2b:** Organizational integration through pro-environmental systems has positive influence on lean organization with sustainability objectives

### SSCM adoption

Implementing sustainability brings radical changes to not only manufacturing operations, but also other areas such as supplier coordination, logistics and distribution involved in the upstream and downstream of a supply chain (McKinnon & Edwards, 2009; So & Sun, 2010; Zheng et al., 2006). Ugochukwu et al. (2012) conducted a literature review on lean SCM journal articles from 1990. The results revealed that these research focus on only supply and manufacture, which has not given enough attention to other supply chain members such as distributors and customers for getting maximum benefits from lean. Implementing lean thinking as a sustainable organizational practice can be better off with ESCs, which help facilitate information sharing for pro-environmental systems among various business units within a company and supply chain partners (So & Sun, 2010; 2011). So et al. (2012) critically reviewed 35 recent SSCM articles, and it argued that companies can recognize trade-offs or benefits in their supply chains by treating sustainability as integral to operations in order to ensure that supply chain partners meet agreed-upon sustainable standards and targets. The regularization (implementation) of SSCM in an organization and the senior management support to maintain it that lean, sustainability and supply chain is a cross-organizational commitment could influence the rate of adoption. As a result, this leads to the last hypothesis, which defines the causal relationship between SSCM adoption and the management commitment of using SSCM in our research:

**H3:** On-going commitment of using SSCM demands its regularization in operations

### METHODS

### Sample profiles

The instrument of this study is derived from the International Manufacturing Strategy Survey (IMSS) (Lindberg et al., 1998). IMSS is an international research network consisting of 20 countries and 600 companies in the world. A sample is selected from Kyoto Protocol signatories. The sample profiles are
shown in Tables 1. The total sample size of this study is 527, which includes 17 Annex II signatories with commitment to ratification. The average firm size is 438. The sample was selected from a larger group of manufacturing firms including both Annex II countries and non-Annex I countries (developing countries). The average firm size of sample obtained from non-Annex I countries is 1294, which is nearly 3 times our sample. Firm size is important as it may affect the adoption of new practices. So and Sun (2010) conducted an empirical study on lean SCM with 558 manufacturing firms in 17 countries. The results revealed that smaller manufacturers at firm size < 600 tend to adopt lean because of their less complex organizational structure. Our sample includes manufacturing firms from industrialized countries, which are required to reduce GHG emissions by 8% below 1990s level (United Nations, 1998) and their experiences are a good reference to the late adopters of sustainability.

Questionnaire was designed with the purpose to reveal the multi-facet of manufacturing strategy and practice. Data was collected from participating countries through random sampling. The average return rate exceeded 35%. Operationalization of research variables in this study is based on the self-developed items derived from the IMSS questionnaire and is substantiated by literature review. Multiple items are used to measure the research constructs. The study intends to include items related to major supply chain participants in measuring SSCM including suppliers, distributors and customers. All items are measured by a five point Likert scale with 1 indicating ‘None’ or ‘Not important’ and 5 indicating ‘High’ or ‘Very important’. Corresponding measurements for lean operations and SSCM of the model are identified. Table 2 summarizes the constructs and their corresponding variables.

### Measurement development

**Measures for lean organization with sustainable objectives**

With reference to Buker (1991) and Womack and Jones (2003), the following six measures are used to operationalize the concept of lean organization: (1) Process focus and streamlining with the aim to simplify overly complex operations, (2) Implementing pull production based on a demand driven principle to better address customer needs, (3) Delegation and knowledge development of workforce to improve operation response time and overall decision processes through staff development, (4) Leaner organization by simplifying span of control, which can be achieved through (a) redesigning operations by investing in ESC infrastructures and pro-environmental systems, and (b) restructuring supply and distribution strategy by adopting green purchasing and green logistics, (5) Continuous improvement with Kaizen methodology through creating an environment of total employee involvement with visible controls and measures, regular housekeeping, and total quality focus, and (6) Organizational workforce
planning with a lean thinking initiative, which requires building human capital through providing education and leadership for workers to work in the group setting.

Measures for organizational integration through pro-environmental systems

The measures are operationalized into seven operations areas supported by most pro-environmental systems and ERP systems (Lin et al., 2011; Klaus et al., 2000) in association with five primary SCM processes (i.e. Plan, Source, Make, Deliver, and Return): (1) Material management (Plan, Source, Make, Deliver, Return), (2) Production planning and control (Plan, Make), (3) Sales management (Plan, Deliver), (4) Distribution management (Plan, Deliver), (5) Purchasing and supply management (Plan, Source), (6) Human resources management (Plan), and (7) Accounting and finance management (Plan).

Measures for SSCM adoption

Satisfactory diffusion of innovations is about the continuous use of an idea after adoption (Rogers, 2003). Our study on SSCM adoption concerns not only its use, but also the investments by both manufacturers and suppliers, which are measured by the level of use over 6 years. Dependent variables that are related to the use of SSCM require manufacturers’ commitment including 2 main concepts: (1) regularization of SSCM measured by the level of use in last 3 years, and (2) on-going commitment to SSCM measured by the level of use over next 3 years. Moreover, the study intends to include items related to manufacturers’ major supply chain members in measuring SSCM, i.e. suppliers, distributors and customers. According to Buker (1991) and Womack and Jones (2003), the degree of collaboration with supply chain members and formulation of associated strategies reflect the extent of realizing lean thinking in operations such that manufacturers can exert a positive influence on their sustainability performance through the transfer of best practices to supply chain partners. Based on the literature review, the measures for SSCM adoption are operationalized as follows: (1) Restructuring towards sustainable supply strategy, (2) Sustainable supplier development, (3) Supplier coordination on planning decision and flow of goods, (4) Restructuring towards sustainable distribution strategy, and (5) Customer coordination on planning decision and flow of goods.

RESULTS

Reliability and validity

In this research, SPSS Statistics 20 software is used in data analysis. Cronbach’s alpha is used in testing construct reliability and alpha coefficient is created for each construct (Chen & Paulraj, 2004). An alpha coefficient is typically considered adequate if it exceeds 0.7 (Cronbach, 1951; Nunnally, 1978). Raykov (1997; 1998) argued that Cronbach's alpha may over- or underestimate reliability, composite reliability (CR) measure of the constructs are calculated as an additional measure, where values exceeding 0.6
Factor analysis is used for testing construct validity. Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy is an index used to examine the appropriateness of factor analysis, which ranges between 0 and 1 with 0.5 as minimum acceptable value (Kaiser, 1974). Convergence validity and discriminant validity are examined (Chen & Paulraj, 2004). Factor loading exceeds 0.60 demonstrates convergent validity (Hair et al., 2006). A model demonstrates discriminant validity if the square root of Average Variance Extracted (AVE) by each construct, which is the average squared factor loading, exceeds the corresponding inter-variable correlation (Fornell & Larcker, 1981; Hair et al., 2006). Appendix Table A illustrates the measurement methods for reliability and validity assessment in this study.

Table 2 and Table 3 summarize the results of reliability and validity tests. The scales of sample tested show sufficient reliability and validity. First, Cronbach's alphas (Table 2) and CR values (Table 3) for all constructs are all good as indicated. Second, the results show desirable convergent validity as all factor loadings in Table 2 exceed 0.60. The diagonal in Table 3 is replaced with the square root of AVE for each construct, and the overall results show reasonable discriminant validity.

Fitness of theoretical model

Structural Equation Modeling (SEM) method is used to test the model fit for evaluating the goodness of predictions and explanatory power (Allen et al., 2009; Jöreskog, and Sörbom, 1993). A two-step method is used: (1) the significance of path is examined, and (2) model fit is then examined by using multiple criteria based on Hu and Bentler (1999). Fit indexes and $\chi^2$ goodness-of-fit statistics obtained from the test are assessed. Because $\chi^2$ is sensitive to sample size and, due to the large sample size in our study, normed Chi-square ($\chi^2$/d.f.) is used (Wheaton et al., 1977). Fit indexes including Normed Fit Index (NFI), Comparative Fit Index (CFI) and Root Mean Square Error of Approximation (RMSEA) are used. Generally, according to the rule of thumb recommended by previous authors, NFI value above 0.9, CFI value above 0.9, RMSEA value below 0.05 are regarded as good fit (Browne & Cudeck, 1993; Hair et al., 2006; Hu & Bentler, 1999). RMSEA between 0.05 and 0.08 is acceptable, but the model is not employable if RMSEA is greater than 0.1 (Browne & Cudeck, 1993). For normed Chi-square, Carmines and McIver (1981) recommended the value be less than 3.
The theoretical model (Figure 1) is tested with SEM method in the AMOS software (Byrne, 2010) with the estimation model obtained in Figure 2. All four hypotheses are significant and accepted with $H_2a$ ($\beta=0.47$), $H_2b$ ($\beta=0.31$), and $H_3$ ($\beta=0.69$) at $p<0.001$ and $H_1$ ($\beta=0.14$) at $p<0.01$, where $\beta$ weights are path coefficients, i.e. the standardized regression coefficients that explain the proportions of variance and the correlations among variables (Jöreskog, and Sörbom, 1993).

In addition, the estimation model is significant with $p=0.026<0.05$ and $\chi^2/d.f.=2.766<3$, and it has a good fitness with NFI=0.988>0.9, CFI=0.992>0.9 and RMSEA=0.049<0.5.

**DISCUSSIONS**

**Model 1** theorizes the relationship between SSCM regularization and the ongoing commitment of using SSCM. The results of SEM in Figure 2 show that $H_3$ ($\beta=0.69$, $p<0.001$) is significant. In addition, the results in Table 2 and 3 indicate that the constructs have good reliability and validity. This implies that SSCM, by incorporating sustainability into key SCM processes including Source, Make, and Deliver, need to be first adopted as practices and demonstrate improvements in key areas of operations through managing manufacturers’ major supply chain counterparts, i.e. suppliers, distributors and customers (Supply Chain Council, 2008). Moreover, the entry into force of the Kyoto Protocol marked an important step in international climate policy. Annex I countries as Kyoto Protocol signatories need to pass legislation to implement sustainability as a national law, which leads to various government policy instruments that trigger the implementation of ‘hard’ measures such as regulations, taxes, and tradable permit systems (Metz, 2010). The new national law and regulations eventually influence various core supply chain activities including supplier management, material procurement, delivery costing and the ultimate pricing of goods and services (Cameron, 2001; Hoffman & Woody, 2008). Manufacturers can take advantage of SSCM only if they put sustainability into use, which involves restructuring existing supply chain strategies and collaborating with major supply chain members to reduce environmental impacts. This represents a sufficient condition to manufacturers committing the ongoing use of SSCM that reinforce the adoption decision already made. These reasons help explain the remarkably good generalization of model 1 to firms in Annex II parties.

**Model 2** theorizes the implementation of lean operations as sustainability practices. Based on the literature review plus further study of lean manufacturing (Cagliano et al., 2006; Oliver et al., 1993; Olson, 2008) and supply management (Bozarth et al., 2009; Ryan, 2001; So & Sun, 2010), we propose two dimensions to study lean thinking in SSCM: (1) internal lean practices, and (2) organizational integration. In particular, So and Sun (2010) studied the adoption of lean thinking in 558 manufacturing
firms enabled with ESCs, the results revealed that adopting lean in daily practices, improvement could attribute to job performance of manufacturing workforces and cost structures through waste reduction and manufacturers’ overall productivity could be increased. Hence, we theorize that the regularization of SSCM is positively influenced by lean organization (H1: \( \beta=0.14, p<0.01 \)) and organizational integration (H2a: \( \beta=0.47, p<0.001 \)) in an ESC, which offers information sharing among various supply chain members including manufacturers, suppliers and distributors. An ESC is also an information platform of the supply chains for underpinning pro-environmental practices through adopting EMS in various supply chain processes. On this ground, organizational integration reinforces the practice of a lean organization that facilitates the use of SSCM in an ESC environment (H2b: \( \beta=0.31, p<0.001 \)).

The hypothesized relationships H1, H2a, H2b and H3 are highly relevant to business logistics activities that move raw materials and finished goods to the final point of sale in the supply chain, where in Annex II countries, green logistics are widely adopted for reducing environmental impact of transport (Harris, 2013; McKinnon & Edwards, 2009). In the countries where carbon taxes are enforced, companies usually measure the relationship between the quantity of goods purchased and the environmental costs of moving them to the collection points, as they realize that costs should be controlled in order to reduce carbon footprint. Manufacturers need to be environmentally aware in managing operations, in particular, logistical activities among trading partners in the supply chains with best practices like lean thinking.

**LIMITATIONS AND FUTURE RESEARCH**

Considering SSCM involves various aspects of SCM including supply policies, manufacturing operations, inventory and item management, and distribution, the manufacturer centric study presents a limitation on the applicability of concepts to non-manufacturing firms in a supply chain. The next stage of the research is to enhance the research model via a survey of sample with a broader coverage of supply chain members. Moreover, So and Sun (2010; 2011) argued that a firm’s position in the supply chain may influence the adoption of lean as contextual factors. It is suggested to study these contextual factors in future research.

Manufacturing firms from developing countries, in particular small to medium-sized enterprises (SMEs) may not be able to completely adopt the emissions reduction initiatives if their governments implement corresponding policy instruments by taking up a more ambitious commitment, for example, firms may need to implement reverse logistics (i.e. Return processes) that support product recovery and goods return to the suppliers, which is an important measure to strengthen the capability of waste reduction. These manufacturers may need facilitation from different types of intermediaries or even government bodies with different types of support ranging from customized to more loosely held support (Klewitz et al., 2012), while large companies are likely to have resources and established policies that enable them to adopt sustainability more easily (Gadenne et al., 2012; Klewitz et al., 2012; Price et al., 2011; Roxas
and Chadee, 2012). With this in mind, a comparative study will be conducted to evaluate the adoption of SSCM by manufacturing firms of different sizes.

**CONCLUSION AND IMPLICATIONS**

The study proposes a systematic approach to develop SSCM and lean operations through combining (a) innovation diffusion theory, i.e. IDT (Roger, 2003), a widely accepted theory (over 34 thousand citations according to Google Scholar) to frame the research model by positioning sustainability as an organizational innovation, and (b) industry best practices in lean thinking (Buker, 1991) and SCM (Supply Chain Council, 2008) to operationalize the variables for empirical testing. The results show that variable (1) and (2) associated with $H_1$ and $H_{2a}$ in relation to *lean organization* and *organizational integration* respectively, are good predictors of SSCM adoption to manufacturers. Moreover, variable (2) associated with $H_{2b}$ is a good predictor of variable (1), which indicates the significance of ESCs in enabling lean organizations and SSCM implementation. Above all, SSCM can become a long-term supply chain practice if manufacturers align their supply chain strategies with sustainability objectives that go beyond their internal activities to suppliers, distributors and customers, this confirming $H_3$.

The study has practical implications. First, the results imply that manufacturers in developing countries may consider going lean before moving toward adopting sustainability for a better chance of succeeding. Second, incorporating sustainability in a supply chain should include major upstream and downstream members (i.e. suppliers, distributor and customers) in order to achieve maximum benefits. Furthermore, creating a culture of empowerment is important to lean implementation (Buker, 1991). This implies that developing human capitals of manufacturing supply chains to embrace lean thinking at work might help get employees’ approval of the new practices. There is a dearth of research on the nexus of lean thinking and Human Resources Management particularly in examining the impact of humanistic values of lean on SSCM. It’s worth paying attention to address this gap in the literature, which could help advance the theoretical base of SSCM beside the research agenda laid down in the previous section.
REFERENCES


### APPENDIX

<table>
<thead>
<tr>
<th>Statistical method</th>
<th>Purpose of use in the study</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cronbach's alpha test</td>
<td>Cronbach's alpha test is a reliability test that assess the degree of consistency between multiple measurements of a variable or item ranging from 0 to 1, with values of 0.60 to 0.70 deemed the lower limit of acceptability (Hair et al., 2006).</td>
<td>Cronbach's alpha is defined in the following formula:</td>
</tr>
</tbody>
</table>
|                             |                                                                                             | \[
\alpha = \frac{N}{N-1} \left[ 1 - \frac{\sum_{i=1}^{N} \sigma_{ii}}{\sigma_{yy}} \right]
\]                                                                                       |
|                             |                                                                                             | where \( N \) is the number of components or items, \( \sigma_{ii} \) is the variance of the observed total test scores, and \( \sigma_{yy} \) is the variance of component \( i \). The cronbach's alpha statistic can be obtained by the SPSS software, which is used for statistical analysis. |
| Factor analysis             | Factor analysis is primarily used for data reduction and summarization, in which the results can be applied to assess the validity of measurement scales (Hair et al., 2006). | The common factors themselves can be expressed as linear combinations of the observed variables:                                              |
|                             |                                                                                             | \[
F_i = W_{i1}X_1 + W_{i2}X_2 + W_{i3}X_3 + \ldots + W_{ik}X_k
\]                                                                                       |
|                             |                                                                                             | where \( F_i \) represents the estimate of \( i \)th factor, \( W_{ik} \) is the weight of factor score coefficient and \( k \) is the number of variables. The statistic is obtainable by using the SPSS computer program. |
| Kaiser-Meyer-Olkin (KMO) test | KMO is a measure of sampling adequacy. It is an index used to examine the result of factor analysis, and KMO values between 0.5 and 0.6 indicate factor analysis is appropriate (Kaiser, 1974). | The index is calculated by comparing the magnitudes of the observed correlation coefficients to the magnitudes of the partial correlation coefficients. The KMO statistic can be obtained by SPSS computer program through conducting factor analysis. |
| Average variance extracted (AVE) | AVE is a measure of the discriminant validity of constructs in the study by measuring the extent to which constructs are different (Campbell & Fiske, 1959; Fornell & Larker, 1981). | AVE statistics can be calculated as follows:                                                                                                   |
|                             |                                                                                             | \[
AVE = \frac{\sum_{i=1}^{N} \lambda_i^2}{N}
\]                                                                                         |
|                             |                                                                                             | where \( \lambda_i \) represents standardized factor loading and \( N \) is the number of item.                                                |
| Composite reliability (CR) | CR is a measure of scale reliability that assesses the internal consistency of a measure, and CR values of more than 0.6 indicating good construct reliability (Fornell & Larker, 1981). | CR statistics can be calculated as follows:                                                                                                   |
|                             |                                                                                             | \[
CR = \frac{(\sum_{i=1}^{N} \lambda_i^2)^2}{(\sum_{i=1}^{N} \lambda_i^2 + \sum_{i=1}^{N} \delta_i)}
\]                                 |
|                             |                                                                                             | where \( \lambda_i \) represents standardized factor loading and \( \delta_i \) is the error variance. |
Figure 1: Theoretical model

Figure 2: Results of estimation model
<table>
<thead>
<tr>
<th>Country</th>
<th>Sample Size [a]</th>
<th>Average Size (Number of Employees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>14</td>
<td>60</td>
</tr>
<tr>
<td>Belgium</td>
<td>32</td>
<td>561</td>
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<tr>
<td>Turkey</td>
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<td>790</td>
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<tr>
<td>UK</td>
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<td>137</td>
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<td><strong>Total</strong></td>
<td><strong>527</strong></td>
<td><strong>438</strong></td>
</tr>
</tbody>
</table>

[a] Sample: Annex II parties (excluding EIT parties and those with no commitment of ratification)

[b] Adapted from Baumert et al. (2005) and EEA (2011)

Table 1: Sample profiles
<table>
<thead>
<tr>
<th>Measures</th>
<th>Alpha Value</th>
<th>KMO</th>
<th>Factor Loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementing Lean Thinking as Sustainable Organizational Practices (Model 2)</td>
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</tr>
<tr>
<td>Lean Organization with Sustainability Objectives</td>
<td>0.754</td>
<td>0.776</td>
<td>0.648</td>
</tr>
<tr>
<td>Obtaining process focus &amp; streamlining</td>
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<td></td>
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<tr>
<td>Implementing pull production</td>
<td>0.650</td>
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<tr>
<td>Delegation and knowledge development of workforce</td>
<td>0.655</td>
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<td></td>
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<tr>
<td>Leaner organization model by simplifying the span of control</td>
<td>0.700</td>
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<tr>
<td>Continuous improvement with Kaizen methodology</td>
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<td>Organizational workforce planning with a lean thinking initiative</td>
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<td>Material management</td>
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<td>Production planning and control</td>
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<tr>
<td>Accounting and finance</td>
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<td>Human resources management</td>
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<td>Continuous Adoption of Sustainable Supply Chain Management (Model 1)</td>
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<tr>
<td>Sustainable SCM Regularization</td>
<td>0.797</td>
<td>0.800</td>
<td>0.715</td>
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<td>Restructuring towards sustainable supply strategy</td>
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<tr>
<td>Sustainable supplier development</td>
<td>0.765</td>
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<tr>
<td>Supplier coordination on planning decision and flow of goods</td>
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<td></td>
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<tr>
<td>Restructuring towards sustainable distribution strategy</td>
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<tr>
<td>Customer coordination on planning decision and flow of goods</td>
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<td>Sustainable SCM Commitment</td>
<td>0.790</td>
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<td>0.744</td>
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<tr>
<td>Restructuring towards sustainable supply strategy</td>
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<tr>
<td>Sustainable supplier development</td>
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<td>Supplier coordination on planning decision and flow of goods</td>
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<td>Customer coordination on planning decision and flow of goods</td>
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Table 2: Results of factor analysis and reliability analysis

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<tr>
<th>Correlation, CR and AVE</th>
<th>CR</th>
<th>AVE</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tbody>
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<td>Lean Organization with Sustainability Objectives</td>
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<td>0.448</td>
<td>0.870</td>
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<tr>
<td>Sustainable SCM Regularization</td>
<td>0.765</td>
<td>0.547</td>
<td>0.506**</td>
<td>0.280**</td>
<td>0.740</td>
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<tr>
<td>Sustainable SCM Commitment</td>
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<td>0.542</td>
<td>0.404**</td>
<td>0.246**</td>
<td>0.687**</td>
<td>0.736</td>
</tr>
</tbody>
</table>

** p = 0.01

Table 3: Correlation, CR and AVE