The influence of lean practices on supply chain performance

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Abstract:

Aims(s): This article aims at investigating which LSCM practices efficiently improve the operational performance of a supply chain

Methodology: To achieve that, a cross-sectional survey was carried out with 113 manufacturing companies undergoing a lean implementation.

Results: Our findings provide evidence for justifying why some LSCM initiatives may find larger barriers than others, compromising their success on the implementation, since implementation efforts might be misguided according to the desired performance improvement.

Practical Implications: An appropriate Supply Chain Management (SCM) is essential for companies impacting their operational performance.

Keywords: Lean supply chain management, Operational performance, Supply chain management, Multivariate analysis.

1. Introduction

A supply chain comprises all activities related to flow and transformation of products, services and information, starting from raw materials to end user (Ballou, 2009). Hence an appropriate Supply Chain Management (SCM) is essential for companies impacting their operational performance in terms of inventory and costs reduction, increased customer satisfaction and processes efficiency, higher quality and improved delivery service level (CHRISTOPHER; TOWILL, 2001; UGOCHUKWU et al., 2012). SCM implies a management change from exclusive improvement efforts oriented to internal problems to focus on the relationships with the other companies both downstream and upstream the supply chain (ALVES FILHO et al., 2004; SRIDHARAN et al., 2005). Further, SCM encompasses the planning and management of all activities involved in supply and acquisition, conversion and all logistics management activities. It also includes coordination and collaboration with partners, who can be suppliers, service providers and customers (QRUNFLEH; TARAFDAR, 2013).

It is verified the incipience of the literature with respect to the addressed topic and, consequently, one research questions can be raised: “which are the LSCM practices that need to be prioritized in order to efficiently improve the operational performance of the supply chain?”. Thus, the objective of this article is to investigate which LSCM practices efficiently improve the operational performance of a supply chain. To achieve that, a cross-sectional survey was carried out with 113 manufacturing companies undergoing a lean implementation.

2. Literature review

The approach of examining the impact of lean implementation based on the assessment of the adoption level of pre-defined practices has been widely used in previous studies (QI; CHU, 2009; RAHMAN et al., 2010; MANZOURI et al., 2013; SHARMA et al., 2015) and seems to be also quite effective in understanding companies’ maturity regarding LSCM. However, according to Karim and Arif-Uz-Zaman (2013), the proper selection of LSCM practices depends on the context of each company and its supply chain. Therefore, the strategy for the transition from a traditional supply chain model to a LSCM cannot be indiscriminately generalized, since the different contextual factors are determinant for such decision (RAHMAN et al., 2010).

Further, some studies (e.g. TAYLOR, 2006; ANAND; KODALI, 2008; VLACHOS, 2015) intend to connect LSCM practices and lean principles. Perez et al. (2010), for example, evaluate the relationship of contextual variables and performance of a supply chain with LSCM practices. Anand and Kodali (2008), later complemented by Jasti and Kodali (2015b), suggest eight pillars for the implementation of LSCM, which are constituted by 82 practices; they are: (i) management of information technology; (ii) management of suppliers; (iii) waste disposal; (iv) JIT production; (v) customer relationship management; (vi) logistics management; (vii) commitment of senior management; (viii) continuous improvement. Tortorella et al. (2017b) empirically validated four bundles of 22 inter-related and internally consistent LSCM practices, which are: customer-supplier relationship management (CSRM), logistics management (LOM), elimination of waste and continuous improvement (EWCI), and top management commitment (TMC). Although there is evidence regarding the positive association between LSCM practices and supply chain performance, existing studies do not explicitly indicate the most effective practices to improving each performance indicators.

With regards to LSCM practices individually, 'kanban' and 'close relationship between customer, supplier and relevant stakeholders' appear to be the most frequently cited in the LSCM studies, which can be attributed to the fact that these practices are included in the precursor studies of LSCM (e.g. LAMMING, 1996; ERRIDGE; MURRAY, 1998; MCIVOR, 2001). In addition, 'kanban' is commonly associated with just-in-time (JIT) deliveries (Dües et al., 2013; Wiengarten et al., 2013), in which the right material is delivered at the expected time, place and quantity (QRUNFLEH; TARAFDAR, 2013). Consequently, its adoption implies a narrowing of information and material flows between suppliers and customers, reinforcing the collaboration between them (Martínez-Jurado and Moyano-Fuentes, 2014). Thus, since the implementation of both practices is closely related (BHAMU; SINGH SANGWAN, 2014), it is reasonable to expect that these practices have been consistently associated with the LSCM studies over time, leading to a high number of research evidence that reports their application.

In turn, there are other LSCM practices that seem to be more sparsely evidenced in the literature. For instance, the establishment of 'distribution centers', which is generally motivated due to potential impacts on transportation costs and order processing (BAKER, 2004), has been recently associated with LSCM implementation. In fact, Taylor (2006) appears to be the first study to suggest the incorporation of this practice into the set of LSCM practices. However, only in Sharma et al. (2015) and Jasti and Kodali (2015a) this practice was actually deemed as a LSCM practice. Thus, from the increasingly understanding and expansion of lean thinking to supply chains, some already acknowledged practices gained considerable attention and began to be treated as part of LSCM implementation.

3. Method

There are three stages to the research method proposed here: (i) questionnaire development and data collection, (ii) clustering of data, and (iii) data analysis. These stages are detailed in the sections to follow.

3.1. Questionnaire development and data collection

Three criteria for selecting the sample of companies were established. First, respondents should include companies from a pre-defined region or nationality, in this case, Brazil, as to reduce the effects of the external environment (e.g. national culture, and socio-economic development), as suggested by Kull et al. (2014). Second, sample should be comprised by companies from different industrial sectors because lean has been expanding over many kinds of companies in recent years (MARODIN et al., 2016). Third, respondents should have experience in lean and a role whose function was directly related to SCM in the company. Questionnaires were sent by e-mail to 497 former students of executive education courses on lean offered by a large Brazilian University since 2008. A first e-mail message containing the questionnaires was sent in January 2016, and two follow-ups were sent in the following weeks. The final sample was comprised of 113 valid responses (representing a response rate of 22.74 percent). Most respondents were from large companies (74%); the majority of companies belonged to the first and second tiers of the chain (65%); and most respondents had up to five years of SCM and lean implementation experience (65%).

The questionnaire has three parts. The first part aims at assessing the level of change over the last five years of the supply chain performance indicators (Pi): (i) supply lead time, (ii) costs with supply and raw material, (iii) inventory level, (iv) delivery service level and (v) quality. A 5-point scale ranging from 1 (worsened significantly) to 5 (improved significantly) is used in the questionnaire. The second part aims to collect information regarding the demographic characteristics of the sample. Thus, companies' contextual variables were coded into two categories each. The first category for tier level comprised companies from the first and second tiers, while the second category consisted of companies from tiers three and four. For plant size, large-sized companies were determined as the ones that presented more than 500 employees, and small-sized were characterized by companies with less than 500 employees, as suggested by SEBRAE (2013). Lean experience was coded into (i) more than five years and (ii) less than five years of LM experience; according to Marodin et al. (2016), who suggest that companies with more than five years of lean implementation might achieve a stage where improvement initiatives are being applied to suppliers and customers and the transition from top-down to bottom-up approach would be completed. Finally, the third part of the questionnaire comprises the assessment of the implementation level of the 22 LSCM practices, as suggested by Tortorella et al. (2017b). These practices were assessed according to a five-point Likert scale (1=low implementation to 5=high implementation).

3.2. Clustering of data

The next step of the proposed method performs the clustering of observations with regards to each supply chain performance indicator. Clustering tools are designed to analyze the relationships within a database to determine if it is possible or not describing such data in a summarized form, by a small number of observations of similar classes (EVERITT, 1980; GORDON, 1999). First we applied the hierarchical method to identify the number of clusters that better categorize the performance level Pi (i=1,…,5) of each indicator. Ward's method was used, which identifies groups of similar size based on the minimum variance of the cluster (Hair et al., 2006). Based on the analysis of the dendrogram, the number of clusters is identified. After that, through the application of the *k*-means clustering method, clusters are rearranged fixing the *k* clusters according to the previous dendogram analysis.

For each supply chain performance indicator, two groups were identified according to their perceived improvement level. Then, by means of a Student's t-test the difference between the average of groups of each indicator was tested, which confirmed a significant difference between these groups' average improvement level (p-value<0.000). For each indicator, respondents with higher average values of Pi were clustered into their corresponding group named 'high performers' (HPi; i=1,…,5); while respondents with lower average values for Pi were included into groups denoted as 'low performers' (LPi; i=1,…,5) for the respective indicator. Table 1 shows the size of clusters for each supply chain performance indicator according to improvement levels (LPi and HPi).

Table 1 – Size of clusters for each performance indicator according to improvement levels

Performance indicator	LP_i	HP_i
1 - Supply lead time	68	45
2 - Costs with supply and raw material	72	41
3 - Inventory level	65	48
4 - Delivery service level	60	53
5 - Quality	45	68

3.3. Data analysis

Firstly, the 22 LSCM practices were combined into four the LSCM bundles according to indications from Tortorella et al. (2017b): CSRM, LOM, EWCI and TMC. Each of the bundles was formed by adding the scores for each of the practices included in the bundle for each responding company. All 22 LSCM practices were entered for PCA (principal component analysis) and varimax rotation was used to extract orthogonal components, and four components were extracted. Thus, the bundles were empirically validated using PCA with varimax rotation and reliability analysis (Cronbach's alfa). Additionally, unidimensionality of each component was verified and confirmed by applying PCA at the component level. All components displayed high reliability, with alpha values above 0.809 (Appendix A). Finally, the response value for each bundle was obtained through the average of the corresponding practices included in the bundle weighed by their respective factor loadings from the PCA.

Secondly, we examined the relationship between the factor scores of the bundles of practices and each of the five performance indicators. Factor scores are the transformed variable values corresponding to a particular data point after the dimensionality reduction (Shaw, 2003). The factor scores of each bundle are assumed to represent the intensity of effort companies dedicate towards the implementation of LSCM practices (input). The performance indicators are seen as the desired output of such effort. Thus, we assessed the problem from an input/output perspective, in which the identification of efficiency plays a key role, especially for companies denoted as HP. In this sense, we focused on distinguishing between the efficient and inefficient high-performer companies (EHP and IHP, respectively), and focused our efficiency analysis on HP cluster.

For that, we considered the factor scores of bundles of practices as ‘inputs’ and the performance indicators obtained from the survey as ‘outputs’. It is reasonable to think about efficiency in terms of the ratio of output (supply chain performance) a company improves with a given level of input (factor scores of bundles) representing the effort dedicated towards LSCM practices. Hence, we used Data Envelopment Analysis (DEA) technique, as previously evidenced in supply chain studies with similar objectives (e.g. LIANG et al., 2006; WONG; WONG, 2007). In essence, such procedure examines the technical efficiency scores given different returns to scale, and determines whether or not the observed levels match the frontier corresponding to a particular scale assumption. Thus, in our case, an output-oriented and constant-returns-to-scale (CRS) model was implemented to distinguish those high-performers belonging to the efficiency frontier (technical efficiency score=1.00; EHPi) from those that do not (technical efficiency score<1.00; IHPi).

Finally, we tested for statistical pair-wise differences in the factor scores averages among these three groups (LPi, IHPi and EHPi). In order to improve results robustness under possibly non-Gaussian data distribution, we applied a non-parametric statistical procedure. We performed the one-sample Kolmogorov-Smirnov test for normality, which is a non-parametric test of the equality of continuous distributions. The obtained results indicated that the normality assumption does not hold (p-value<0.05) for the majority of the cases.

4. Results

Table 2 shows the results from the DEA application on HP companies. For each supply chain performance indicator, our analysis provided two different groups (IHPi and EHPi) with their respective sizes n. It is noteworthy that these groups presented a fairly well-balanced amount between efficient and non-efficient companies; except for the indicators 'Quality' and 'Inventory level', which appear to have significantly more occurrences of inefficient companies (n_5=49 e n_3=34, respectively) than efficient ones (n_5=19 and n_3=14, respectively). Further, the cluster denoted as LP companies remained with the same amount of respondents indicated in Table 1, since the DEA analysis was focused only on the HP cluster.

Table 2 – Number of companies '*n*' within each HP group (LP_i, IHP_i and EHP_i)

Performance indicator	LP_i	IHP_i	EHP_i
1 - Supply lead time	68	30	15
2 - Costs with supply and raw material	72	25	16
3 - Inventory level	65	34	14
4 - Delivery service level	60	33	20
5 - Quality	45	49	19

Table 3 displays the significant results (p-value<0.10) for the pair-wise differences on factor scores of LSCM bundles between groups of companies for each indicator. For supply lead time, two bundles of practices appear to have significant differences between groups: CSRM and LOM. Surprisingly, the adoption level of CSRM seems to be significantly higher in LP companies than in IHP companies. This result suggests that, despite supply lead time has poorly been improved on the past few years, LP1 companies appear to be more widely implementing practices such as 'close relationship between customer, supplier and relevant parties', 'open-book negotiation', 'hoshin kanri' and 'development of supply chain KPIs' than HP1 companies. This difference is particularly observed when comparing the factor scores of companies whose perceived improvements are resultant from unequally greater efforts, entailing an inefficient implementation (IHP_1). On the other hand, the average factor score for LOM is significantly higher in EHP_1 companies than in LP_1 or IHP_1 companies. Thereby, practices such as 'material handling systems', 'standardized work procedures to assure quality achievement', 'inbound vehicle scheduling', among others, appear to be widely adopted by companies that identified significant improvements on supply lead time. Further, if properly adopted, little implementation efforts of these practices can lead to meaningful increases in the performance of this indicator. Thus, companies that aim at reducing supply lead time can potentially benefit from the implementation of these practices without expending or investing a significant amount of resources.

Table 3 – Significant pair-wise differences of factor scores averages of LSCM bundles between groups of companies (LP_i, IHP_i and EHP_i)

Performance indicator	LSCM bundle	Company	*n*	Average	Lower value	Upper value	Company	*n*	Average	Lower value	Upper value	Average diff.
Supply lead time	CSRM	LP_1	68	0.619^{*}	0.603	0.636	IHP_1	30	0.605^{*}	0.581	0.628	-2.4%
	LOM	LP_1	68	0.702^{***}	0.679	0.728	EHP_1	15	0.757^{***}	0.698	0.808	7.9%
		IHP_1	30	0.707^{**}	0.673	0.745			0.757^{**}	0.698	0.808	7.1%
Costs with supply and raw material	CSRM	LP_2	72	0.614^{**}	0.599	0.629	IHP_2	25	0.594^{**}	0.571	0.584	-3.3%
Inventory level	LOM	LP_3	65	0.721^{***}	0.698	0.745	EHP_3	14	0.777^{***}	0.721	0.835	7.7%
		IHP_3	34	0.709^{***}	0.674	0.742			0.777^{***}	0.721	0.835	9.6%
Delivery service level	CSRM	LP_4	60	0.615^{*}	0.698	0.745	IHP_4	33	0.602^{*}	0.672	0.741	-2.2%
	TMC			0.680^{*}	0.674	0.742	EHP_4	20	0.706^{*}	0.722	0.834	3.9%
Quality	EWCI	LP_5	45	0.697^{*}	0.665	0.727	EHP_5	19	0.734^{*}	0.692	0.775	5.4%

* significant at 10%/ ** significant at 5%/ *** significant at 1%

Regarding costs with supply and raw material, LSCM practices related to CSRM presented a significant difference when comparing respondents from LP_2 and IHP_2. Similarly to supply lead time, the average factor score for these practices is higher in LP_2 companies, indicating that their implementation may be shallower in companies that claim significant improvements on costs but inefficiently address those throughout CSRM. Hoberg et al. (2017) argue that sometimes a closer relationship between customers and suppliers may imply maintaining business regardless of practiced prices. In fact, companies that highly adopt these practices shift their approach with customers and suppliers from the usual trading mentality to a collaborative partnership, in which additional aspects are taken into consideration besides costs, such as efforts on concurrent product development, reinforcement of communication and information sharing, long-term cooperation and commitment, etc (PETERSEN et al., 2005). Therefore, our results corroborate to such findings.

With regards to inventory level, significant differences were found for the average factor scores of LOM for two paired analyzes: LP_3 / EHP_3, and IHP_3 / EHP_3. In both analyzes the results showed that EHP_3 companies have been adopting these practices more extensively than LP_3 and IHP_3 ones. This outcome also evidences that companies that search for reducing their inventory can efficiently achieve it through the small efforts on the implementation of this bundle of practices. Further, results suggest that as LOM implementation increases, performance improvement may increase at even higher rates. This results somewhat converges to the findings from Waller et al. (2006) and Williams and Tokar (2008), who emphasize that the integration of traditional logistics decision, such as 'outbound transportation' and 'establishment of distribution centers', might positively impact inventory policies and lead to a differentiated performance level.

For delivery service level within the supply chain, bundles CSRM and TMC presented significant differences between LP_4 / IHP_4 and LP_4 / EHP_4, respectively. Analogously to what was observed for indicators 'supply lead time' and 'costs with supply and raw material', CSRM appears to be more extensively implemented in LP_4 companies than in IHP_4 ones. This result can be justified by the fact that companies facing delivery issues, either with customers or suppliers, tend to enhance their communication and focus on information sharing with respect to products, transportation and schedules; while companies achieving the expected delivery service level may keep their usual intensity on CSRM practices implementation (KANNAN; CHOON TAN, 2006; MASELLA; RANGONE, 2000). In turn, TMC implementation seems to be more pervasive in EHP_4 than LP_4. In this sense, results evidence that the adoption of practices such as 'two-way feedback assessment', 'value chain management', 'keiretsu (suppliers play a strategic role marshalling the efforts of their own suppliers)' and 'kyoryokukai (suppliers' association that enhance lateral communication among suppliers, and act as an extra bulwark against customer opportunism)' may entail significant increases in delivery performance with minimum efforts of implementation. This result converges to the findings from Adamides et al. (2008) and Qrunfleh and Tarafdar (2013), who argue that increased levels of collaboration and commitment among suppliers can improve supply chain responsiveness and agility to new demands.

Finally, results obtained for quality indicate that practices encompassed by EWCI bundle are more likely to be widely implemented in EHP5 than in LP_5 companies. In other words, our results suggest that practices such as ‘pull system’, ‘levelled scheduling’ and ‘value stream mapping’ may efficiently drive significant improvements on quality performance, which justifies their higher adoption level in EHP_5 companies. According to Bhamu and Singh Sangwan (2014) and Sharma et al. (2015), these practices aim at improving flow through waste reduction. In this sense, smoother and more agile material and information flows are more likely to provide the identification of abnormalities that can impact quality, such as rework, scrap or misinformation. Thereby, our results corroborate to these findings and reinforce the importance of implementing these LSCM practices in supply chains that aim for better quality performance.

5. Conclusions

In this paper, we have studied which LSCM practices efficiently improve the performance of the supply chain. This research suggests two major findings. First, there are certain bundles of LSCM practices that may efficiently provide performance improvements of the supply chain. Second, the identification of this set of practices according to the aimed performance indicator allows companies to establish a prioritization on their LSCM efforts. Implications of these results are of considerable importance and relevance for both researchers and lean practitioners.

This study allows to better comprehend the effects of the implementation of bundles of LSCM practices on the improvement of specific supply chain performance indicators. In fact, we provide evidence for justifying why some LSCM initiatives may find larger barriers than others, compromising their success on the implementation, since implementation efforts might be misguided according to the desired performance improvement. We provided empirical evidence about which LSCM bundles efficiently drive significant performance improvements in different supply chain indicators, managers from manufacturing companies could compare that with the pace of their LSCM implementation. Our results suggest that the greatest opportunities lie in increasing the use of practices encompassed in LOM, EWCI and TMC, leading to different performance improvements. Nevertheless, practices included in the CSRM bundle appear to indicate contradictory findings, particularly for supply chain delivery, costs and lead time.

In a more general way, the study provides a tool for managers to assess the state of LSCM in their specific supply chain and, eventually, re-design their implementation process according to the desired output. Our research provided empirical evidence that it is possible to improve supply chain performance by implementing specifically LSCM practices. That is particularly important in a country that has high interest rates and needs to compete in a global market with minimum resources (either capital or human) availability.

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APPENDIX A – LSCM practices, bundles and factor loadings

LSCM practices	Factor loadings			
	CSRM	LOM	EWCI	TMC
$LSCM_2$-Close relationship between customer, supplier and relevant parties	**0.587**	0.052	0.137	0.300
$LSCM_{15}$-Open-book negotiation	**0.745**	-0.045	0.187	0.190
$LSCM_{17}$-Hoshin Kanri (policy deployment and development of a strategy for the supply chain)	**0.801**	0.211	0.156	0.149
$LSCM_{18}$-Development of supply chain KPIs	**0.531**	0.309	0.213	0.298
$LSCM_4$-Efficient and continuous replenishment	0.399	**0.601**	0.142	0.225
$LSCM_{12}$-Material handling systems	0.301	**0.721**	0.177	0.102
$LSCM_{13}$-Standardized work procedures to assure quality achievement	0.117	**0.794**	0.032	0.119
$LSCM_{14}$-Open-minded and in depth market research conducted jointly (joint understanding of end-user requirements so that all players can work towards providing customer value)	0.135	**0.596**	0.174	0.348
$LSCM_{16}$-Inbound vehicle scheduling	0.409	**0.734**	0.086	-0.054
$LSCM_{19}$-Outbound transportation	0.441	**0.592**	0.067	0.132
$LSCM_{20}$-Establishment of distribution centers	231	**0.742**	0.213	0.087
$LSCM_{22}$-Functional packaging design	0.213	**0.701**	0.259	0.039
$LSCM_1$-Kanban or pull system	0.527	0.020	**0.637**	0.201
$LSCM_3$-Leveled scheduling or heijunka	0.162	0.067	**0.689**	0.031
$LSCM_7$-Win-win problem solving methodology	0.423	0.076	**0.671**	0.289
$LSCM_8$-Value chain analysis or value stream mapping	0.009	0.219	**0.773**	0.286
$LSCM_{21}$-Consignment stock	0.111	0.210	**0.715**	-0.006
$LSCM_5$-Two-way feedback assessment	0.299	0.105	0.039	**0.779**
$LSCM_6$-Value chain management	0.219	0.157	0.399	**0.588**
$LSCM_9$-Keiretsu (suppliers play a strategic role marshalling the efforts of their own suppliers)	0.202	0.157	0.499	**0.602**
$LSCM_{10}$-Kyoryokukai (suppliers' association that enhance lateral communication among suppliers, and act as an extra bulwark against customer opportunism)	0.168	0.212	0.276	**0.723**
$LSCM_{11}$-Intervention strategy (customer is able to cooperatively intervene in the supplier's business operation and bring about change for better)	0.012	0.298	0.065	**0.683**
Eigenvalues	8.667	1.987	1.678	1.324
Initial percent of variance explained	38.81	8.60	7.69	5.79
Rotation sum of squared loadings (total)	3.83	3.55	3.21	2.78
Percent of variance explained	17.54	16.21	14.82	12.33
Cronbach α (sample n = 113)	0.811	0.825	0.809	0.821

Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalization. The bold numbers indicate which practices were allocated to which bundles.