Lean Six Sigma and Sustainability: Literature Review Analysis

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Abstract

Lean Six Sigma (LSS) has contributed to many organizations around the world to adopt this in their operations to become more competitive. The evolution of production systems and government requirements has led companies to develop strategies to achieve more sustainable operations. Evidences suggest that LSS and sustainability (LSSS) contribute to organization performance and environmental issues. However, the theoretical contribution from LSSS has been insufficiently discussed in literature. This article aims to analyze articles on literature reviews on the LSSS theme, in order to present its main characteristics. This study verifies what has been published on the theme in order to point out similarities and differences in research findings. Additionally, there is a comparison on what has been discussed in LSS literature reviews to what is available in LSSS literature reviews. The results show that there are few publications on LSSS. Even so, there are similarities in research findings among LSS and LSSS literature reviews, which can lead to many research opportunities in the theme.

Keywords: *Lean Six Sigma, Sustainability, and literature review.*

1. Introduction

Lean Production (LP) and Six Sigma (SS) are quality management methods that have gained popularity since they were first proposed. They are also often used in an integrated way, called Lean Six Sigma (LSS). The term LSS was first used in early 2000 (George et al., 2004) to describe the combination of LP and SS (Sheridan, 2000). This integration aims to overcome the deficiencies from both methodologies and take advantage of positive aspects from each of them.

The success of LSS, as one of the best continuous improvement methodologies, has led many organizations around the world to adopt it in their operations. The use of this methodology has made these organizations more competitive (Cherrafi et al., 2016) and has made improved quality possible in product operations (Alhuraish et al., 2017; Chugani et al., 2017).

The evolution of production systems coupled with government requirements and policies have guaranteed the control of the environmental impacts from production activities and forced companies to develop strategies to achieve more sustainable operations. Practical and theoretical evidences suggest that LSS and sustainability (LSSS) contribute to the performance of organizations by stressing environmental issues. However, the theoretical contribution on LSSS has been insufficiently discussed in literature (Cherrafi et al., 2016; Chugani et al., 2017).

Literature review is indeed an important research effort, as it is not merely a review of previous writings, as it answers specific research questions (Thomé et al., 2016). It is also a methodology locating existing studies that selects and evaluates contributions, analyzes and synthesizes data and reports the evidence in such a way as to make it possible to draw reasonably clear conclusions on what is and what is not known (Denyer; Tranfield, 2009).

The successful applications of literature review in psychology, medical research and social sciences have been used as a justification for disseminating this research method to other fields, such as Operations Management (OM) (Thomé et al., 2016). Furthermore, a literature review can identify the conceptual content of the subject being studied (Meredith, 1993) and it helps to contribute to theory development (Seuring; Müller, 2008).

Empirical work in the field of Production Engineering, and especially in OM is available in literature, converges on the knowledge of best practices that can be replicated in other organizations, dealing with similar cases or analogous situations. However, the volume of scientific information leads to the need for syntheses to facilitate its understanding in determining conclusions based on the combination of results from multiple sources.

The motivation for this research emerged based on this context and it becomes feasible by searching for literature reviews addressing LSS and sustainability. Thus, this article aims to analyze literature review on the theme of LSS and sustainability in an integrated manner, in order to present the main characteristics from these publications, to verify what has been discussed on this theme and to point out similarities and differences among the theoretical investigation findings. Additionally, a comparison will be presented on what has been discussed in LSS literature reviews related to what has been studied in LSSS literature reviews. Thus, some research questions (RQ) can be established: RQ1: What are the main contributions from LSSS literature reviews, regarding the gaps in this theme? RQ2: How are the reviews on LSS literature similar and differ from what has been presented in LSSS literature reviews?

The next section describes the methodology used for collecting the literature reviews. The third section discusses the characteristics of literature reviews and the last section presents the conclusions.

2. Methods

Table 1 shows the steps adopted for performing the literature reviews. It is based on Tranfield et al. (2003) for the selection of articles on LSSS literature reviews. This method has also been adopted by literature reviews, such as Albliwi et al. (2015), Sreedharan and Raju (2016), Aleu and Van Aken (2016; 2017) and Vashishth et al. (2017).

Table 1. Summary of research phases and processes for LSSS literature reviews

Research Phase	Description	This Research
1. Research Purpose	Define the purpose of literature review research.	Present the main characteristics of LSSS literature reviews, verifying what has been discussed about the theme and pointing out similarities and differences between what is being discussed regarding the context of LSS and LSSS literature reviews.
2. Research Protocol	This includes the scope of the study, the search strategy for identifying relevant studies and the inclusion and exclusion criteria.	- Scope: literature review articles on LSS and sustainability. - Strategy: The following keywords were used: lean, six sigma, lean sigma, sustainability, green, literature review. - Inclusion and exclusion criteria: all qualified international scientific publications should be covered.

Table 1. Summary of research phases and processes for LSSS literature reviews (continued …)

Research Phase	Description	This Research
3. Applying Criteria	Search criteria helps to ensure that only the most relevant articles are used for research purposes (or) the less important articles are excluded.	- Inclusion criteria: No restriction for publication date; Portuguese, English or Spanish languages; Literature review dealing with LSS and Sustainability, this means LP, SS and Sustainability in an integrated way; - Exclusion criteria: Materials developed by consulting firms, reports, work teams from research groups, technical reports, non-scientific database references.
4. Literature Searches	Online databases enabling access to full texts from relevant scientific publications.	Searches in the following electronic databases: Compendex (Engineering Village), EBSCO, Emerald, IEEE Xplore, Science Direct (Elsevier), Scopus, Web of Science and Wiley Online Library.
5. Selecting studies	Publication selection based on the characteristics defined in the research protocol.	Articles selection is based on the application of established relevance criteria and characteristics presented in the research protocol (second row on Table 1).
6. Quality Assessment	Publications quality is evaluated by characteristics defined by the researcher.	For rigor reasons conferences papers (Cherrafi et al., 2016) were not included.
7. Data Extraction and 8. Synthesis	Data extracted from selected publications for the purpose of synthesizing them using appropriate techniques, such as quantitative or qualitative analysis, or both, for combining the extracted facts	Data will be extracted considering research gaps. This means: main contributions identified in the article. The following items will be used as criteria for data analysis: scope (purpose), journals that contributed to LSS literature reviews, electronic databases used by the articles, research scope, types of publications of articles (conference article, journal article; book; thesis) and country of origin of the article.
9. Reporting the Research	Report in detail the systematic review of literature, as well as the obtained results.	Preparation of an article for an event and/or journal.
10. Dissemination	Publish the systematic review, generating contribution in the field of knowledge.	Publication/submission of a scientific article sharing the theoretical scientific contribution in LSSS.

A discussion of the selected articles using the described criteria in this section is presented in the next topic.

3. Discussion of Lean Six Sigma and Sustainability (LSSS) literature reviews

Table 2 presents the purposes of selected literature reviews, Garza-Reyes (2015) point out the limitations and compatibilities of sustainability, LP and SS and proposes a theoretical model for LSSS integration. Cherrafi et al. (2016) present a proposal for the integration framework of LP, SS and sustainability.

Table 2. Purposes of selected literature reviews.

Reference	Purpose
Garza-Reyes (2015)	Critically review the green lean approach and highlight its limitations; Examine the compatibility of the green, lean and SS concepts; and propose SS, and specially its problem-solving methodology DMAIC, as an approach to help enhancing the effectiveness of green lean initiatives.
Cherrafi et al. (2016)	Present a review and an analysis on the literature concerning a possible model for integrating three management systems: lean manufacturing, SS and sustainability.
Chugani et al. (2017)	Investigate, through a systematic review of the existing academic literature, the environmental (green) impact of using quality and operations improvement methods such as LP, SS and LSS.
Freitas and Costa (2017)	Carry out a systematic study of LSS impacts on organizations, analyzing their relation to organizational sustainability through the triple bottom line (TBL) perspective.
Ruben et al. (2017)	Capture the perspectives of the LSS from industries and discuss the development of practices through a systematic literature review in the following perspectives: LSS frameworks, decision-making related to LSS, performance measurement for LSS, applications of LSS, LSS linkage to other manufacturing strategies and LSS to environmental insights.

Chugani et al. (2017) evaluate the environmental impact on energy savings and the use of natural resources by adopting LP, SS and LSS. Freitas and Costa (2017) study the organizational sustainability in the application of the three TBL pillars. Ruben et al. (2017) analyze several articles on various aspects including an environmental focus.

The International Journal of Lean Six Sigma (IJLSS) has published the largest number of literature reviews in LSSS and has published three articles. The Journal of Cleaner Production and the International Journal of Advanced Manufacturing Technology have each contributed one article.

Table 3 shows the databases used by the selected articles and the most commonly used are Emerald, Science Direct (Elsevier), Springer Link, and Taylor & Francis. Chugani et al. (2017) did not report the databases they used. The authors Garza-Reyes (2015) and Cherrafi et al. (2016) searched the largest number of databases.

Table 3. LSSS literature review databases.

Databases	References					
	Garza-Reyes (2015)	Cherrafi et al. (2016)	Chugani et al. (2017)	Freitas and Costa (2017)	Ruben et al. (2017)	Total
EBSCO	X	X				2
Elsevier Science Direct	X	X			X	3
Emerald	X	X			X	3
Google Scholar	X	X				2
IEEE Xplore	X				X	2
Inderscience	X				X	2
ISI Web of Science	X					1
Metapress		X				1
Scopus		X		X		2
Springer Link	X	X			X	3
Subito		X				1
Taylor & Francis	X	X			X	3
Wiley	X	X				2
Total	10	10	-	1	6	

Table 4 presents some parameters, such as period of literature reviews, types of publication and number of articles collected by LSSS literature reviews.

Table 4. Parameters of LSSS literature reviews.

Reference	Research Period	Type				Quantity
		Conference Articles	Journal Articles	Books	Thesis	
Garza-Reyes (2015)	1997-2015		X			59
Cherrafi et al. (2016)	1990-2015		X		X	118
Chugani et al. (2017)	2000-2015		X			70
Freitas and Costa (2017)	2003-2014	X	X			48
Ruben et al. (2017)	2000-2016	X	X	X		70
Total						365

All the research period studies lasted longer than ten years, but Cherrafi et al. (2016) consider a 25 year research time scope. Additionally, Cherrafi et al. (2016) are the authors who have the largest sample of publications. Freitas and Costa (2017) and Ruben et al. (2017) used both journal and conference articles to compose their publication sample. The other authors presented in Table 4 used only journal articles. Also, 365 publications were reviewed as stated on Table 4, which brings about a broader overall view of what has been happening regarding LSS and sustainability.

Table 5 shows United Kingdom (UK) as the region that has contributed the highest number of LSSS literature reviews. This country has been pointed out as the one that frequently publishes reviews on LSS only behind the United States (US) (Zhang et al., 2012; Albliwi et al., 2015; Sreedharan, Raju, 2016; Yadav, Desai, 2016; Shokri, 2017).

Table 5. Countries publishing LSSS literature reviews.

Country	Reference	Quantity	%
Brazil	Freitas and Costa (2017)	1	20
India	Ruben et al. (2017)	1	20
Morocco	Cherrafi *et al.* (2016)	1	20
UK	Garza-Reyes (2015); Chugani *et al.* (2017)	2	40
Total		**5**	**100.00**

It is possible to verify that the authors from countries publishing LSSS literature reviews are the ones where the least number of LSS empirical research projects is performed, as is the case of the US, as it was not shown on Table 5.

In fact, the authors from the US publish more empirical studies on LSS. This may indicate that authors from countries on Table 6 consider LSSS as not yet being fully established, leading the researchers from those countries to seek theoretical information on the subject. Some similarities will be presented below comparing LSS to LSSS literature reviews.

3.1 Similarities comparing LSS to LSSS literature reviews

This section synthesizes some similarities in the analyzed literature reviews. This set of information was compared to other LSS literature reviews. They are grouped on Table 6.

Table 6. Similarities comparing LSS literature reviews to LSSS literature reviews.

Subject	LSS Literature Reference	LSS and Sustainability Literature Reference
Automotive industry has applied LSS most frequently.	Shokri (2017); Muraliraj *et al*. (2018)	Cherrai *et al.* (2016)
There is increasing application of the LSS in the health field	Zhang *et al.* (2012); Cionã and Radu (2015); Shokri (2017); Muraliraj *et al*. (2018)	Freitas and Costa (2017)

Table 6. Similarities comparing LSS literature reviews to LSSS literature reviews. (continued …)

Subject	LSS Literature Reference	LSS and Sustainability Literature Reference
The number of articles published in agro-industries and food industries are minimal.	Sreedharan and Raju (2016)	Cherrafi *et al.* (2016)
Jiju Antony is the author who publishes on LSS most frequently.	Endler *et al.* (2016); Yadav and Desai (2016); Muraliraj *et al*. (2018)	Freitas and Costa (2017)
The journal that publishes LSS most is the International Journal of Lean Six Sigma.	Yadav e Desai (2016); Chugani *et al.* (2017); Sreedharan and Raju (2016); Shokri (2017); Muraliraj *et al*. (2018)	Cherrafi et al. (2016); Freitas and Costa (2017)

Table 6 shows that five similarities were found. LSS literature reviews presented a greater number of research findings than LSSS literature reviews, since they are more widespread in literature. There were no divergences found in research findings when comparing LSS literature references to LSS and sustainability literature references. Table 7 presents some information (research findings) specific to LSSS literature reviews not included in LSS literature reviews. According to Tables 6 and 7 the most active authors in LSS research are from the US. The same occurs in LSS and sustainability (Cherrafi et al., 2016).

Table 7. LSS literature reviews and sustainability findings.

Subject	Sample Reference
The authors from US are the most active in LSS and sustainability research.	Cherrafi *et al*. (2016)
The Journal of Cleaner Production is the journal that contributes the most to LSS and sustainability articles.	Cherrafi *et al.* (2016), Chugani *et al.* (2017)
Jiju Antony is the author who publishes the greatest number of LSS articles.	Cherrafi *et al.* (2016)
Research on LSS and sustainability is based on recent articles.	Cherrafi *et al.* (2016), Chugani *et al.* (2017)
5S and Kaizen are the most effective LSS tools for reducing environmental and social impacts from manufacturing companies.	Cherrafi *et al.* (2016), Chugani *et al.* (2017)
There is not much information in the literature on SS and sustainability in organizations.	Cherrafi *et al.* (2016), *Chugani et al.* (2017)
LSS can help to achieve a sustainable environment.	Cherrafi *et al.* (2016), *Chugani et al.* (2017)
Application of LSS and sustainability is scarce in small and medium sized companies.	Cherrafi *et al.* (2016)

LSS has been mostly applied in the industry sector and the greatest concentration in the automotive industry. Growth was also identified in applying LSS in the health field (Zhang et al., 2012, Freitas, Costa, 2017, Shokri, 2017 and Muraliraj et al., 2018). On the other hand, Cherrafi et al. (2016) and Sreedharan and Raju (2016) have shown that the number of articles published in agro-industries and food industries was insignificant.

The data agrees on the author who publishes most frequently on LSS and LSSS, i.e. Jiju Antony. The International Journal of Lean Six Sigma publishes most on LSS and the Journal of Cleaner Production published on LSS and sustainability research most frequently based on recent publications.5S and Kaizen LSS tools are effective in reducing environmental and social impacts from manufacturing. Cherrafi et al. (2016) even include MFV, cellular manufacturing, standardized work, visual management, JIT, SMED, supplier relationship, pokayoke, SS, statistical process control, and layout reorganization. According to Cherrafi et al. (2016) and Chugani et al. (2017) the literature does not supply enough information on the effect of SS on sustainable aspects. This information generates research opportunities on SS and sustainability. The same authors also confirm that the LSS can make

sustainability achievements possible.

3.2 Main contributions from Lean Six Sigma and Sustainability literature reviews

The contribution of several researchers is remarkable and extremely important from LSSS literature reviews. The main contributions or strengths are highlighted on Table 8.

Table 8. Strengths and main contributions from LSSS literature reviews.

Reference	Main Contributions
Garza-Reyes (2015)	Provide various attributes on Sustainability, LP and SS (definition, objective, focus, principles, measures, common key performance indicators, manufacturing, product development, inventory, waste, lead time, people, customers, suppliers, techniques, and main tools); Propose a conceptual integration model on the purpose of overcoming incompatibilities and divergences between Sustainability and LP through SS; Present similarities, compatibilities and divergences between Sustainable LP and SS.
Cherrafi et al. (2016)	Present drivers and barriers to integrate LP, SS and sustainability; Provide nineteen benefits from LP/SS integration and sustainability; Display an extensive list of benefits that LSS tools can generate when is integrated in sustainability; Provide an overview of the synergies and divergences among LP, SS and sustainability; Present a list of fifteen integration methods for LP, SS and Sustainability, pointing out its main contributions, limitations and sectors for which it was developed; Propose success critical factors for LSS integration and sustainability; Present a theoretical model on LSSS integration.
Chugani et al. (2017)	Provide discussions focused on each methodology, which involves presenting the impact of LP, SS and LSS on resources.
Freitas and Costa (2017)	Present twenty-five impacts from LSS on organizational sustainability of organizations that have been classified based on TBL sustainability (financial, social and environmental pillars).
Ruben et al. 2017)	Additionally to literature review, the authors have developed a generic framework for LSS implementation based on an environmental approach.

3.3 Gaps and guidelines for future research

This study is the innovative in the sense of analyzing LSSS literature reviews articles. In order to encourage new research on this theme and synthesize information, gaps in literature were highlighted, which may be considered as a basis for the development and continuity of studies on this theme. Table 9 concentrates the opportunities for theoretical and practical developments of LSS and LSSS literature reviews.

Table. 9. Common research opportunities for LSS and LSSS literature reviews.

Topic	LSS Literature Reference	LSS and Sustainability Literature Reference
Empirical LSS research is lacking in different types of organizations.	Zhang *et al.* (2012), Yadav and Desai (2016), Muraliraj *et al.* (2018)	Cherrafi *et al.* (2016)
Use indicators to evaluate the impact of the LSS on company performance.	Yadav e Desai (2016), Vashishth, Chakraborty and Antony (2017)	Garza-Reyes (2015)
Develop metrics for quantifying LSS performance.	Pacheco (2014), Albliwi et al. (2014)	Cherrafi et al. (2016)
Explore the relationship between LSS and the human factor.	Albliwi et al. (2015)	Cherrafi et al. (2016)

Table. 9. Common research opportunities for LSS and LSSS literature reviews. (continued…)

Topic	LSS Literature Reference	LSS and Sustainability Literature Reference
There is no standard model or a roadmap to be followed for LSS deployment, as a holistic LSS deployment approach is lacking, appropriate to a given problem, scenario, situation or type of industry and segments (public, manufacturing, services, health care, higher education).	Zhang *et al*. (2012), Albliwi *et al*. (2014), Albliwi, Antony and Lim (2015), Endler *et al.* (2016), Sreedharan and Raju (2016), Yadav e Desai (2016), Raval and Kant (2017), Vashishth, Chakraborty and Antony (2017), Muraliraj *et al.* (2018)	Cherrafi *et al.* (2016)
Explore the relationship between LSS and sustainability/environmental management considering different aspects.	Albliwi et al. (2015), Sreedharan and Raju (2016), Yadav, Seth and Desai (2017)	Garza-Reyes (2015), Cherrafi *et al.* (2016), Chugani *et al.* (2017)
There is a growing trend of research in LSS and sustainability.	Cionã e Radu (2015), Endler *et al.* (2016)	Garza-Reyes (2015), Cherrafi *et al*. (2016)
Requirements for covering the pre-implantation phase of LSS, to ensure the suitability and capacity of the organization before starting any LSS project, as there is no clear guidelines for LSS in the early stages of deployment.	Albliwi *et al.* (2014, 2015)	Cherrafi *et al.* (2016)

Cherrafi et al. (2016) point out seven major gaps in LP, SS and Sustainability: i) performance measurement system for specific industries and processes; ii) development of integrated model applicable to various types of industries; iii) focus on small medium enterprises (SMEs) to help them successfully implement LP, SS and Sustainability; iv) research on the applicability of LP, SS and Sustainability in service industries; More research related to LSSS and human factors; vi) Extend the implementation of LP, SS and Sustainability to emerging and underdeveloped countries; and vii) Requirements to cover the pre-implementation phase of LP, SS and Sustainability. The authors also state that research on SS or LSS and sustainability integration is scarce, as the majority of the researchers have begun to focus on these themes after the successful integration of LP and Sustainability. According to Cherrafi et al. (2016) recently, some authors, including Garza-Reyes et al. (2014), Banawi and Bilec (2014) and Garza-Reyes (2015b) recognized the need to integrate SS as part of the LP and Sustainability approach.

According to Garza-Reyes (2015) there is a strong requirement for validation of compatibility in the concepts of sustainability, LP and SS, for example, establishing this model in quantitative and empirical terms and testing it to seek its statistical validity. The authors also claim the literature still lacks a conceptual framework integrating sustainability, LP and SS as a unique approach. Validation is necessary through empirical application in real industrial scenarios or through simulation, as well as the creation of this conceptual framework. The authors also stress the need for exploring the definition of possible limitations in the integration of sustainability, LP and SS.

Freitas and Costa's (2017) research showed that social and environmental pillars should be better exploited by LSS projects through the selection of projects and indicators related to the guidelines of these pillars. Organizations also need to carry out their projects so that the achieved benefits from one of the pillars do not generate negative impacts on the other sustainability pillars, thereby ensuring a better balance among them and better performance for the organization.

Chugani et al. (2017) pointed out the lack of articles studying the impact of SS on the environment and sustainability. These authors also highlight that the positive or negative consequences on the

environment, as a result of SS implementation have not yet been fully exploited. Environmental incentives for various organizations wishing to implement SS have also not been exploited. The context of the following aspects can be considered: a) If LSS implementation helps organizations become more environmentally sustainable; b) If environmental sustainability pressures affect the choice of quality improvement programs, which are challenges from implementing LP and sustainability and; c) If the inclusion of sustainability dimension requires a new theoretical foundation for quality improvement.

According to Chugani et al. (2017) the effects from quality improvement methods on environmental performance still remain in the early stages. There is still not enough studies for the purpose of analyzing the impact on Sustainability, LP and SS in quality management journals. The authors also inquire regarding the combination of Sustainability, LP and SS, as to which method should be used for achieving maximum productivity and positive results and how to properly select them in order to get the best performance. Chugani et al. (2017) believe that the best method for adapting to the culture, industry and nature of the organization should be chosen. However, more research efforts are required to help organizations on deciding to select the best methodology for each situation.

4. Conclusions

This article analyzed LSSS literature reviews, presenting their main characteristics, as well as verifying what has been discussed on theme and pointing out similarities among research findings. This is the first study on reviewing articles on LSSS literature reviews. This research contributed to the field of LSSS knowledge, condensing it into single work evidences based on literature and research opportunities that can guide future studies on several aspects of manufacturing and sustainability.

We suggest analyzing LSSS implementation roadmaps in future studies and drafting a model considering current aspects related to value chains, for example: Industry 4.0. It even deals with theoretical aspects on LSS and sustainability in organizations or practical results and lessons learned on the theme, from literature review article databases to achieve relevant evidence for researchers who are searching for ideas and essential knowledge bases for experts and practitioners when looking for what can be improved in implementing LSS and sustainability strategy.

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