DOES LEAN MEAN SUSTAINABLE?  
EXPLORING LINKAGES THROUGH A SYSTEMATIC LITERATURE REVIEW  

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Lean manufacturing evolved from the Toyota Motor Corporation as means to improve productivity by reducing waste. Nowadays, lean manufacturing is disseminated throughout the world, among different industries and segments. The expansion of the lean philosophy brought up new connections, and one of them is the linkage with manufacturing sustainability. Indeed, it has been found that lean practices are potentially supportive in order to achieve environmental and social performance, besides economic performance. However, systematically integrating lean and sustainability from a triple bottom line perspective can still be challenging for academics and practitioners. The objective of this research is to review the literature regarding the linkages between lean manufacturing and sustainability through a systematic literature review. After a structured selection process, it was collected a sample of 72 papers about the subject. A bibliometric analysis was provided as a way to characterize the literature in this field, and the identified relationships between lean and sustainability were summarized in conceptual maps. It was found that a significant portion of the studies (41.67%) has a specific focus on the green aspect of sustainability, whilst the broader perspective of the triple bottom line is approached by a smaller subset of papers (27.78%). Moreover, the relationship between lean manufacturing and the social aspect of sustainability is still missing in the literature.

Palavras-chave: Lean manufacturing; Sustainability; Systematic literature review.
1. Introduction

The present scenario involves the growth of customer demands for products and services that are environmentally and socially sustainable, as well as the compliance with governmental requirements, which altogether have now forced companies to rethink their one-dimensional view about profitability (GARZA-REYES, 2015). Thus, the integration between lean manufacturing and sustainability has been increasingly discussed in the academic field, along with corporate responsibility and a significant rise on the links between lean and sustainability (MARTÍNEZ-JURADO; MOYANO-FUENTES, 2014).

The green paradigm is focused on the minimization or reduction of environmental impact, while lean manufacturing is aligned with reduction of waste and non-value activities. According to Piercy and Rich (2015), these two paradigms relate in the sense that waste generation is directly associated with unnecessary use of energy and utilities, as well as with air and water pollution.

A considerable portion of the existing literature on the topics of lean and sustainability is related to environmental benefits aligned with lean manufacturing, leaving the social aspects with little or no attention (DUES; TAN; LIM, 2013; GARZA-REYES, 2015). This observation supports the idea that a more holistic view of sustainability can be derived when analyzing its synergies with lean manufacturing.

The main objective of this study is to investigate the relationships between lean manufacturing and sustainability through the lens of the triple bottom line (ELKINGTON, 1997), in which sustainability can be understood as a way of providing a balance between the economic, environmental and social aspects. Hence, it is considered that the synergies between lean thinking and sustainability can involve the social and economic aspects rather than solely the environmental ones.

Therefore, this paper was driven by the following research questions:

- RQ#1: What relationships between lean manufacturing and sustainability can be found in the literature through the lens of the triple bottom line?
- RQ#2: How can lean practices be aligned with the triple bottom line dimensions according to the literature?

Answers for these questions were formulated through a systematic review of the literature. Thus, Section 2 describes the research method, while Section 3 presents a descriptive analysis.
of the sample of papers collected. Section 4 is aimed to discuss the most important findings, and Section 5 offers general conclusions about the research.

2. Research method

To provide answers for the proposed research questions, procedures of systematic review were performed to collect consistent data to be analyzed. Thus, the framework used in this study is the one proposed by Tranfield et al. (2003), which a systematic review consists of three stages: planning, conducting and reporting.

2.1. Stage 1: Planning the review

The first stage consisted of delimiting the subject area of research, which was decided to comprise the topics of lean manufacturing and sustainability. Cross-disciplinary and alternative views must be considered when assessing a research theme (TRANFIELD; DENYER; SMART, 2003). Thus, the following fields of study were found to tackle the connections between lean manufacturing and sustainability: Environmental Sciences, Industrial Engineering, Green Technology, Business and Management.

The review must include papers from academic journals that discuss relationships between lean manufacturing and sustainability regarding the environmental, social and economic aspects of a business. Hence, a simple protocol was created to help in guiding the selection of papers: the sample must contain material that considers sustainability issues, and, at the same time, can help in answering the research questions concerning the relationships with lean manufacturing.

To help in planning the review, an exploratory search was previously performed in a non-structured way on the topics of lean manufacturing and sustainability. This step was important to identify the main concepts in this field and to define the search strings that should be used.

2.2. Stage 2: Conducting the review

The first step in this stage was the establishment of keywords and search strings to collect the articles. Hence, only papers that meet the selection criteria, supported by the protocol listed in Stage 1, were incorporated into the review. Through Stage 2, ISI Web of Knowledge was used as the database for sample collection, in which the search strings presented in Table 1 were used.
In the selection of papers, the initial sample obtained by using such search strings was composed of 227 papers. From these 227 papers, 169 consisted of articles and reviews from academic journals, excluding thereby 58 papers from the initial sample. Next, the second filter consisted of selecting appropriate categories inserted in the ISI Web of Knowledge database that would fit the fields of study listed on the protocol from Stage 1. From this second filter, 132 papers remained on the sample, thus excluding 37 papers.

Table 1 – Search strings used for sample collection

<table>
<thead>
<tr>
<th>Operator</th>
<th>String</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>AND</td>
<td>&quot;lean production&quot; OR &quot;lean manufact*&quot; OR &quot;lean management&quot; OR &quot;lean system*&quot; OR &quot;lean approach&quot; OR &quot;lean process*&quot; OR &quot;lean practice*&quot; OR &quot;lean thinking&quot; OR &quot;Toyota Production System&quot; OR TPS</td>
<td>Topic</td>
</tr>
<tr>
<td>AND</td>
<td>sustainab* OR &quot;triple bottom line&quot; OR 3BL OR &quot;sustainable development&quot;</td>
<td>Topic</td>
</tr>
<tr>
<td>AND</td>
<td>green OR &quot;environmental sustainability&quot; OR &quot;social sustainability&quot; or &quot;economic* sustainability&quot;</td>
<td>Topic</td>
</tr>
</tbody>
</table>

The final filter consisted of a title and abstract analysis. The objective in this step was to delete any paper that did not meet the criteria proposed in the review protocol. From this procedure, 60 papers were excluded, resulting in a final sample of 72 papers.

2.3. Stage 3: Reporting the review

The report of results was performed through the creation of structured tables listing all the articles from the sample and identifying the aspects of the triple bottom line discussed by each paper. Graphs were also made for descriptive analysis, and conceptual maps were prepared to highlight the main findings.

3. Descriptive analysis

One of the first conclusions that can be drawn in the sample of papers is that this is a recent research topic. Figure 1(a) presents a chronological summary of publications since 2005, which is the year of the first publication in the sample. An increasing growth trend can be noticed in papers since 2012, with 93% of papers of the sample. It is noteworthy that the sample includes articles dated until July 2018, which presented a remarkable number of papers for just half of a year. These results show the relatively novel nature of this field of research and the increasing interest over the years.
Of the 72 papers selected for this review, 64 papers (89%) were research articles and eight papers (11%) were literature reviews. The distribution of papers is depicted in Figure 1(b). The graph in Figure 1(b) only shows journals with two or more publications selected from the total number of 27 journals, with the rest featuring only one paper per journal labeled as “others”. A considerable portion of 31 papers (43.1%) of papers was published in the Journal of Cleaner Production. It is not a surprising observation since this journal is focused on environmental and sustainability issues. On the other hand, the high concentration in only one journal points out the need for spreading this research topic to other academic communities.

Figure 1 – (a) Number of papers per year; (b) Distribution per journal; (c) Dimensions of sustainability addressed

<table>
<thead>
<tr>
<th>Journal Abbreviation</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>JCP – Journal of Cleaner Production</td>
<td>43.1%</td>
</tr>
<tr>
<td>IJPE – International Journal of Production Economics</td>
<td>6.9%</td>
</tr>
<tr>
<td>IJLSS – International Journal of Lean Six Sigma</td>
<td>5.6%</td>
</tr>
<tr>
<td>IJOPM – International Journal of Operations &amp; Production Management</td>
<td>6.9%</td>
</tr>
<tr>
<td>JMTM – Journal of Manufacturing Technology Management</td>
<td>4.2%</td>
</tr>
<tr>
<td>SUS – Sustainability</td>
<td>4.2%</td>
</tr>
<tr>
<td>PPC – Production Planning &amp; Control</td>
<td>2.8%</td>
</tr>
<tr>
<td>RCR – Resources, Conservation and Recycling</td>
<td>2.8%</td>
</tr>
<tr>
<td>Others</td>
<td>26.4%</td>
</tr>
</tbody>
</table>

Figure 1(c) shows the distribution of the dimensions of sustainability addressed in the sample. An amount of 30 publications (41.67%) discusses the environmental aspect of the triple bottom line. This result is consistent with the observation made by Cherrafi et al. (2016), with the green aspect receiving the most attention from current research. Moreover, Martínez-Jurado and Moyano-Fuentes (2014) found that the research stream aligned with

Source: Authors
environmental sustainability in lean systems has been predominant since 2001. The social aspect was observed not to be approached solely, yet its association with the environmental aspect consisted of an amount of six papers (8.33%). No studies addressed the social and economic aspects jointly. This finding is aligned with the observations made by Martínez-Jurado and Moyano-Fuentes (2014), who found that the social dimension of sustainability receives less attention than the economic and environmental dimensions. The total number of studies that considered all three dimensions of sustainability was 20 (27.78%). This number is relatively low, given that the contemporary understanding of sustainability is closely related to the integration between those three dimensions. Even though the triple bottom line is a very well established concept, it seems that much of the current research has neglected it.

4. Discussion

The analysis of the literature on the interrelationships between lean manufacturing and sustainability through the triple bottom line has provided the identification of some aspects included in the three pillars: environmental, economic and social. Figure 2 summarizes such findings and how they correlate to the aspects of lean and sustainability through a conceptual map. Each aspect was found through guided reading of the most recent and most cited articles in the sample. The aspects described in Figure 2 are management initiatives or performance criteria linked to the three pillars of sustainability.

Figure 2 – Lean manufacturing and the triple bottom line
In addition, a second map (see Figure 3) was built correlating lean practices to environmental, social and economic aspects of sustainability considering the current literature. It is a summary of the results found to guide how these practices are associated with sustainability. Both maps provide answers to the research questions proposed in the introduction section since they elucidate linkages between lean manufacturing and sustainability through the lens of the triple bottom line.

Figure 3 – Lean practices and sustainability dimensions
4.1. Lean manufacturing and the environmental pillar

A central objective of lean thinking is to use fewer resources and improve productivity while reducing costs. This premise is environmentally friendly since the rational use of resources implicates on less power and water consumption, raw material and waste treatment. Albeit the fields of lean manufacturing and sustainability have been studied and evolved independently of each other, lean and environmental aspects seem to have a symbiotic relationship.

Indeed, Martínez-Jurado and Moyano-Fuentes (2014) found in their study that environmental improvements derived from the implementation of lean principles were attained in an indirect form, considering that no strategies were proposed to achieve green aspects of production. Such synergy is supported by Dües et al. (2013), stating that the alignment of lean and green practices is a catalyst for the conduction of sustainable operations. Moreover, the same study indicates that lean practices have a potentially positive impact on the environment since they are carried in a way to promote efficient and rational use of resources.
Albeit Martínez-León and Calvo-Amodio (2017) show that the number of positive impacts of lean on sustainability is greater than the number of negative ones, the authors point to the ethical issue of resource consumption in a lean system for permitting sustainable development. For instance, Mollenkopf et al. (2010) found that manufacturing sites that apply lean practices have a larger emission of volatile organic compounds than non-lean plants. However, according to the argument of Martínez-León and Calvo-Amodio (2017), negative effects are derived by the manner that an organization implements and carries lean practices, hence being based on their ethical set of values. Nevertheless, the same authors call for better understanding of potential conflicts between lean manufacturing and environmental issues.

The review conducted by Garza-Reyes (2015) showed that environmental performance in an organization could be affected both positively and negatively by lean manufacturing. The former is that lean manufacturing was found to ease the conduction of environmentally friendly practices through social aspects, such as people and community involvement and proper worker training. On the other hand, the latter is based on the lack of a strong ethical component by many organizations, which seek for efficiency and productivity improvements while not considering trade-offs between environmental and economic performance. It is consistent with the argument given by Martínez-León and Calvo-Amodio (2017) about ethical issues.

4.2. Lean manufacturing and the economic pillar

Arguments favorable to the economic pillar of sustainability are explicitly constructed in the articles by Mollenkopf et al. (2010) and Pampanelli et al. (2014). The former discusses the alignment of lean supply chain and sustainability aspects as a potential construct to achieve financial goals and customer satisfaction, while the latter demonstrates that operational costs in a production cell can be minimized employing lean and green practices. It can be noticed that in these papers the relationship between economic and environmental issues is evident. A suitable term for this relation is the “eco-efficiency” of an organization (CARVALHO et al., 2017). Kleindorfer et al. (2005) affirm that promoting eco-efficiency is both economically and environmentally friendly since these aspects converge in the point of poor use of resources in the form of economic and environmental wastes, which are related directly to lean principles.
Martínez-Jurado and Moyano-Fuentes (2014) found that the social aspects of the human factor and cultural change are crucial for achieving and sustaining economic performance from lean and sustainable practices. The author also highlights that it is still necessary to conceptualize frameworks and methods to assess economic performance derived from the integration of lean and sustainable actions.

Usually, managers are supposed to consider that sustainable initiatives are initially expensive due to regulatory policies and new operational investments to fit international certifications criteria, for instance. Nonetheless, the relationship between economic performance and sustainable actions can be recognized as positive, providing enhancements on product quality, consolidation of the supply chain, product and process innovation, cost savings and the possibility to access new markets (PIERCY; RICH, 2015). Furthermore, dealing with economic and environmental/social trade-offs is still a challenge for operations management practitioners (KLEINDORFER; SINGHAL; VAN WASSENHOVE, 2005).

4.3. Lean manufacturing and the social pillar

One principle of lean manufacturing is to promote workers engagement and use their know-how to enhance productivity. This principle can be realized by continuous improvement of the workforce through training and delegation, with involvement being achieved by the promotion of their skills. Martínez-León and Calvo-Amodio (2017) pointed out that positive outcomes on the social aspect of an organization could be attained through the application of lean and green practices, thus showing that the socio-environmental perspective is evident. As an example, they point to the problem-solving and skill enhancement of workers in a lean environment, which can increase motivation, job satisfaction, and employee commitment.

A relevant contribution from the research of Martínez-Jurado and Moyano-Fuentes (2014) is that considerable attention has been given to how lean manufacturing affects people and community, as well as safety and health in the workplace. They also argue that some success factors for the proper implementation of a sustainable lean system are related to worker motivation, effective communication, problem-solving training, and teamwork.

Intuitively, increasing productivity and reducing costs demand more pressure on workers. In response to such a problem, lean enhances teamwork. Such action is aligned with what Piercy and Rich (2015) described as “lean implementation changes at workplace level”, focusing on the engagement of the workforce for innovation and satisfying social relationships. Moreover,
better working conditions are considered as a common goal of lean and sustainable operations.

Carvalho et al. (2017) list synergies between lean management and social sustainability, such as improved health and safety, clean and organized work environment through 5S, minimization of conflicts, local community development, and increased employee morale and commitment.

Although aspects related to workers are relevant in terms of social sustainability, it is worth noting that this is a limited approach. This sustainability pillar encompasses addressing a larger set of stakeholders, concerning, for instance, local communities around manufacturing facilities. However, this perspective is still scarce in the analyzed literature.

5. Conclusion

Global market competition and product quality have been forcing changes in manufacturing systems, with the sustainable aspect receiving growing attention. Along with the need for waste elimination, decent working conditions and a satisfactory return of assets have been aligned with sustainable practices as a way to increase competitiveness. Considering such a context, the present article examined the existing relations between lean manufacturing and sustainable practices as a way to understand how correlations can be made between these two constructs.

Synergies between lean manufacturing and sustainability have been discussed in the literature, with authors trying to establish a solid basis for the construction of effective models for implementation. Such efforts are receiving growing attention when it comes to building and implementation of lean-green models, yet most of these models do not regard social aspects explicitly.

The motivation of this literature review was to find synergies and interactions between lean manufacturing and sustainability, considering the triple bottom line framework. This study provided information on how lean and sustainability can relate and a descriptive analysis of the sample collected, characterizing the current state-of-the-art on this field. A relevant contribution of this research is the overview of papers that are focused on each aspect of the triple bottom line and their respective combinations, providing general guidance on how the research in this field has been conducted in the last years. However, further research is necessary to elucidate researchers and practitioners on how lean and sustainability can be
associated effectively to improve productivity, reduce costs, enhance the quality of life, and mitigate the environmental footprint of modern companies. By the way, some relevant paths for future research emerge from this paper, as can be seen in Table 2.

As in any study, this paper is not exempt from limitations, and it is important to recognize them. First, the data were collected from a single database (ISI Web of Knowledge), which implicated in a limited collection of results. Second, the sample was not obtained in a randomized and double-blinded manner as suggested by Tranfield et al. (2003), which may restrict the validity of the research since the selection process is not immune to subjectivity and bias. Moreover, a deeper investigation and data collection from other databases could have led to a more comprehensive analysis of the existing relationships between lean and sustainability.

Table 2 – Paths for future research

<table>
<thead>
<tr>
<th>Research question</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>How could lean manufacturing be integrated with the social aspects of sustainability?</td>
<td>Despite some attempts to elucidate this issue, it remains an unclear topic in the literature, especially considering other stakeholders beyond manufacturing workers.</td>
</tr>
<tr>
<td>How to overcome the potential trade-offs between lean and sustainability?</td>
<td>Even though many authors argue the synergy between lean and sustainability, trade-offs cannot be ignored. The hard issue is to find the appropriate balance between both systems.</td>
</tr>
<tr>
<td>How could lean thinking be incorporated into a balanced performance measurement system of the triple bottom line dimensions?</td>
<td>Companies usually have difficulty to cope with multiple and sometimes conflicting, dimensions of performance. Future research could focus on the development of a lean and sustainable performance measurement system.</td>
</tr>
<tr>
<td>Are there contextual differences influencing the integration between lean and sustainability?</td>
<td>Given the popularity of lean throughout the world and in different industries, some linkages between lean and sustainability might be context-dependent. It could be a very fertile research field for the next years.</td>
</tr>
</tbody>
</table>

Source: Authors

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