

Exploring Connections between Lean and Sustainability – A Systematic Literature Review

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Abstract *Since 1998, a body of work has been developing relating to the possibility of overlaps between lean manufacturing and organisations' efforts to become more sustainable (in terms of environmental, social and economic performance – or some combination of these). We feel it is time for a review of these works, both to understand the “landscape” (e.g. trends in publishing on the subject and sub-areas that have or have not received attention) and to explore the lean and sustainability connection. This paper introduces the two subject areas whose intersection we plan to investigate, and explains how the systematic literature search was carried out. We then discuss the trends and the answers to our research questions; we find that there are many definitions for each of our subjects, and that most papers do not rely on a theoretical “lens”. Motivations for integration are many but most commonly cited are the better outcomes from lean, green, social, customer and other stakeholder's perspectives. This field shows plenty of scope for further work, including a need for more empirical studies.*

1. Introduction: The importance of lean and sustainability, moving beyond lean and green

This paper is the first step of a larger research project investigating lean and sustainability perspectives. The aim of this research project is to explore how organisations can be more efficient and improve their sustainability impacts.

Since the late 1990s, there has been a growing stream of literature considering the intersection of lean and sustainable practices. Many studies have discussed links between lean and environmental impact reduction, with perhaps the most obvious connection being that waste reduction is central to both; it is one of the core tenets of the lean philosophy [1] At the same time, amongst key writers in environmental management and corporate social responsibility (CSR) there have been increasing calls for improvements in resource efficiency and productivity, designing products to utilise resources more productively and minimizing environmental impacts[2] [3] This can entail reducing waste, improving efficiency in manufacturing processes, creating better products, or improving yields [4]. For example, Interface of Atlanta doubled revenues and employment, and tripled profits by creating an environmentally friendly system of recycling floor coverings for businesses. [4]

Previous research attempting to link lean and sustainability has tended to predominantly focus on the environmental aspects of sustainability (lean and

green). Our research aims to move the research agenda forward by investigating the full social, economic and environmental of sustainability. We also see an opportunity to take stock of what has been done in this growing field of research and inform future research. In particular we are keen to identify ways to strengthen theoretical contributions in the field. Hence in this paper we address the following research questions:

1. How do authors define lean, sustainability, and the “sustainable lean” overlap?
2. What theories are used in sustainable lean papers?
3. What motivations do we know of for organisations to adopt “sustainable lean” methods?
4. What gaps and opportunities for further work have been identified and remain unfilled?

The remainder of the paper is structured as follows. First we describe the methodological approach to our review of the literature. Next we highlight some the key preliminary findings and then discuss those in relation to our research questions. Finally we draw conclusions to inform future research.

2. Methodology

This paper is based upon a systematic review of 143 articles identified in relevant journals across the fields of supply, purchasing and operations, and business ethics/sustainability. A structured literature review is a methodical approach aiming at reducing biases and increasing transparency [5]. This implies a detailed description of the steps taken to select, scan and analyse the literature [6]. Hence performing a structured literature review increases replicability and provides an appropriate means of synthesising a rapidly growing field of knowledge [7]. In addition systematic literature reviews are a form of data collection that enables “integrating a number of different works on the same topic, summarizing the common elements, contrasting the differences, and extending the work in some fashion” [8: 8]. It is therefore a valuable methodology to discuss future research implications.

The first stage of this structured literature review consisted in a key-word search of journal articles in the databases Business Source Premier and ABI/Inform Global. The search used a combination of terms related to both sustainability and lean. Full details regarding the keyword combinations used for the search are provided in Table 2. The keywords for sustainability were chosen based on the most prominent of sustainable operations management (OM) and sustainable supply chain management (SSCM) found in the literature. These definitions are compiled in Table 1 and show the trend to incorporate the typical three dimensions of sustainability (environmental, economic, social). Through our keywords we expect to have encompassed the green and social dimensions. Lean as a philosophy arguably already addresses economic sustainability as long-term performance. The results were then filtered according to their sources. It was decided to limit the scope of the review to academic peer-reviewed publications, which were perceived

Table 1. Key definitions of sustainable OM and SCM

References	Definitions
[9]	We use the term sustainability to include environmental management, closed-loop supply chains, and a broad perspective on triple-bottom-line thinking, integrating profit, people and the planet into the culture, strategy and operations of companies (p.482)
[10]	The management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account, which are derived from customer and stakeholder requirements. (p. 1700)
[11]	The strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key inter-organisational business processes for improving the long-term economic performance of the individual company and its supply chains. (p. 368)
[12]	The designing, organizing, coordinating, and controlling of supply chains to become truly sustainable with the minimum expectation of a truly sustainable supply chain being to maintain economic viability, while doing no harm to social or environmental systems. (p.45)

as more likely to lead to a comprehensive coverage of the relevant literature and help address the research questions in detail. We did not specify a list of journal in order to be able to scope a large range of research and reflect the diversity of approaches in the field. In terms of time scope, no start date was specified and we searched up to 31st August 2014, which was the most recent complete month when we started the search.

Table 2. Keyword combinations used in the literature search

Lean	AND	Sustainable Sustainability Sustainable Development Environmental Green Social Ethical
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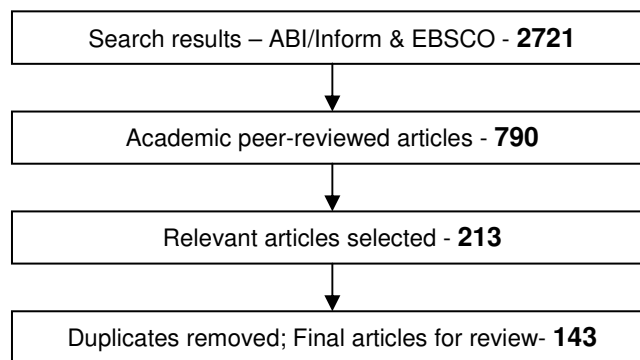
Two of the authors conducted the keyword search independently and then gathered their results in order to ensure consistency and eliminate duplicates. Keyword combinations were divided between them. Each author recorded the outcomes of every single stage of the search for each keyword combination in an excel table. This enables providing an overview of the search process as illustrated in Figure 1 below.

The journal articles are currently being analysed using data extraction tables. These tables have allowed classifying the information presented by the articles into

different categories (basic description, lean conceptualisation, sustainability/lean overlap, theoretical perspectives, sustainability dimension, methodological concerns, findings and future research/gaps) and comparing the way in which authors have operationalised the concepts of lean and sustainability.

The selected articles have been partially reviewed and therefore this paper presents findings and discussions that should be considered as work-in-progress. When analysing the final sample of papers, the authors are mindful of eliminating papers that are irrelevant. This implies that Figure 1 will evolve in the future as a result of the analysis. As shown in the following sections, patterns and striking features already emerge from the analysis, and provide basis for discussion.

Figure 1. Search process and results



3. Findings

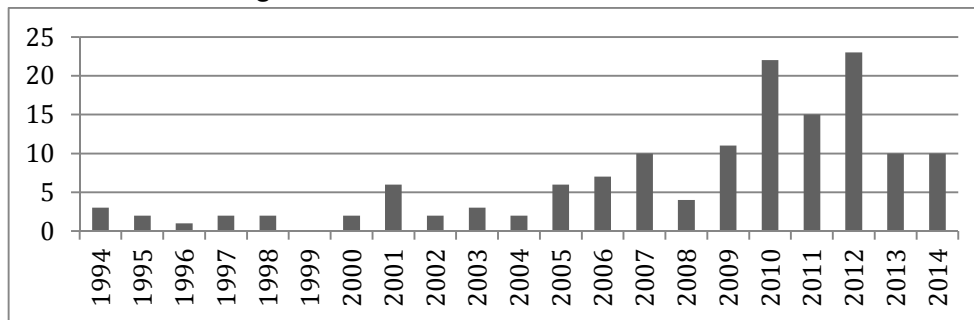
This section starts by presenting the general descriptive statistics from the analysis of the papers. We then present separately the findings related to lean conceptualisation and sustainability issues as a way to partially answer our first research question.

a. General trends in the literature

In our search, we did not find any articles older than 1994. Figure 2 shows the distribution of the articles over the years. The vast majority of our sample was published post-2005 (118 articles, approx. 83%). The period 2009-2012 appears to have been particularly prolific for this area of research. This possibly coincides with a peak in conceptual contributions in related field such as sustainable supply chain management where some influential conceptual frameworks were introduced in 2008 [10, 11] stimulating further research in the direction of achieving improvement while addressing broader societal and environmental impacts. In addition, there may be some connection with the first commitment period of the Kyoto Protocol (2008-2012), which encouraged industry and research to seek ways to achieve more energy efficient production approaches.

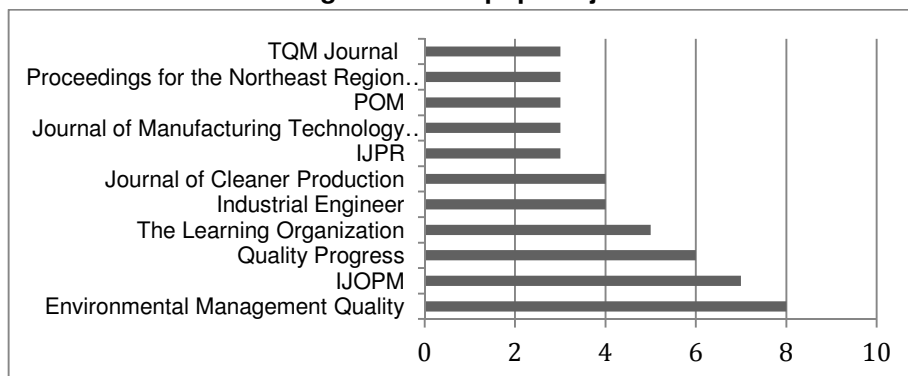
Figure 3 shows the most “popular” journals in which the articles have been published. By “popular” we mean the ones that appear most frequently in our results. We consider that journals that have 3 or more articles to be popular considering that there is a long list of publications where 2 articles appear. The top 4 journals are Environment Quality Management, International Journal of Operations and Production Management, Quality Progress, and The Learning Organization. Interestingly these journals represent a good mix of disciplinary focus and only one of them is specifically targeted at environmental research.

Figure 2. Distribution of articles over time



Finally, going back to the search results enabled us to identify some initial patterns regarding the connections between lean and the different dimensions of sustainability. Table 3 shows the results associated to each keyword combination.

Figure 3. Most popular journals



The link between lean and the environmental dimension of sustainability has been more researched. The link between lean and social aspects remains relatively under-explored. It must be noted that in the sustainability category, we are still currently analysing paper to ensure that the understanding of sustainability goes beyond economic prosperity and performance. It appears from the early stages of our analysis that when mentioning sustainability as a broad term rather than environmental or social, most articles seem to refer to green aspects. A particularly striking finding from Table 3 is the dearth of search results from combining lean

with the terms “sustainable development” and “ethical”, which may already signal some gaps in research but also give an indication of conceptualisations of both lean and sustainability that tend to prevail in the literature.

Table 3. Search results by dimension of sustainability

	Keyword combination	N	Total
Sustainability	LEAN + SUSTAINABLE	28	79
	LEAN + SUSTAINABILITY	43	
	LEAN + SUSTAINABLE DEVELOPMENT	8	
Green	LEAN + ENVIRONMENTAL	62	92
	LEAN + GREEN	30	
Social	LEAN + SOCIAL	41	42
	LEAN + ETHICAL	1	

4. Definitions

The in-depth literature review is still ongoing and the following findings relate to the partial in-depth review that has so far been completed. To select the papers for this partial review, the 143 unique references from the final articles for review category (see Figure 1, above) were sorted by first author’s name to give a fairly random selection, and, starting with the second half of this selection, the first 50 articles that were available (6 were discounted at this stage as the articles could not be accessed) were reviewed in detail.

These 50 articles were firstly further categorised according to relevance on closer reading. 14 were directly relevant (i.e. they made some reference to both lean manufacturing as a systematic attempt to improve business processes and sustainability or environmental or social impacts, and the interaction between the two), 26 were partially relevant (i.e. they addressed either lean or sustainability as we define them, but not necessarily their interaction) and 10 were not relevant (neither lean nor sustainability as we define them were addressed). The rest of the findings are taken from the 40 articles that were directly or partially relevant.

Methods used within these 40 articles were noted; some articles used several methods, but 13 were opinion pieces, there were 16 based on case studies, 5 reported on model-building of some form, 4 gathered data using interviews, 2 each used literature reviews, questionnaires, and some form of participant-observation. Finally there was one paper that used quantitative data (from life-cycle analysis) and one that used hyperbolic social epistemology. The papers are a good reflection of the date range of the whole sample, with the earliest dating from 1994 and the most recent from 2014.

a. Lean conceptualisation

12 articles did not make any attempt to define lean; the definitions used in the remaining 28 are set out in table 4. 32 lean descriptors could be identified in the articles’ descriptions; unsurprisingly, waste and cost reduction are the most

commonly-cited descriptors, used by 14 and 10 articles, respectively, although this does raise the comment that 14 articles that did define lean did not mention waste; it is also surprising that worker empowerment or involvement is only cited once, and Continuous Improvement and Efficiency only three times each, as these would seem fundamental to implementation of lean.

Table 4 – Number of articles citing lean descriptors

Lean descriptor(s)	Number of articles citing
Waste	14
Cost reduction	10
Quality	9
Value	7
Based on Toyota/Toyota Production System (TPS); time compression; Resource efficiency or “doing more with less”; Customer responsiveness	5
Just in time (JIT) or reduction of over-production; Inventory or buffer stock reduction; HR or management practices	4
Continuous Improvement; A philosophy or strategy; Efficiency; Process focused/Process improvement; Increased productivity; Standard work	3
Flexibility; Flow; Space; Total Productive Maintenance (TPM); the Voice of the Customer; considering the whole supply chain	2
Radical product innovation; Automation; Changing from batch-and-queue to one piece flow; Reduction of development time; Jidoka or autonomation; Push and Pull; Rationalisation; Simplification; Workforce involvement and empowerment	1

Although 18 of the articles used only one descriptor, others used a combination of up to eleven.

b. Sustainability issues

30 articles did not attempt any definition of sustainability (although it should be noted that some articles discussed elements of sustainability only, such as workforce welfare or Environmental Management Systems (EMSs) – see below for further breakdown of paper focii within sustainability). Table 5 below shows the occurrence of sustainability descriptors within the 10 articles that did attempt a definition; again, articles often combined a number of descriptors within their definition. It can be seen that in both cases triple bottom line [13] descriptions (including social, environmental and economic sustainability) were among the most popular, although still only used in half of the papers that provided a definition of sustainability.

Table 5 - Number of articles citing sustainability descriptors

Sustainability descriptor(s)	Number of articles citing
Recycling or reduction of waste to landfill; Triple bottom line; Corporate Social Responsibility (CSR)	3
Environmental aspects; stakeholder view of sustainability; Number of accidents	2
Safety hazards; EMS; Life cycle impacts; Compliance; Brundtland's[14] definition; Economic sustainability of firm; Energy consumption; Water use; Biomimicry	1

Considering again all 40 of the relevant or partially relevant papers, each considers some form of linkage between lean and one or more of elements of sustainability, 25 of which were identified within these papers. Table 6 below shows the occurrence of these sustainability elements within all 40 papers.

Table 6 – Number of articles focussing on sustainability elements

Sustainability descriptor(s)	Number of articles citing
Environmental aspects	5
Recycling or reduction of waste to landfill; Triple bottom line; CSR	4
Stakeholder view of sustainability; Safety hazards; EMS; Workforce health and wellbeing	3
Number of accidents; Life cycle impacts; Industrial relations	2
Compliance; Brundtland's definition; Economic sustainability of firm; Energy consumption; Water use; Biomimicry; C02 emissions / other Greenhouse gases; Resource use; Ethics; Consideration of the whole supply chain; Green design; Process (green) improvement; Societal impacts; Air emissions	1

Table 6 shows us that the elements of sustainability discussed in conjunction with lean are quite disparate, with 14 elements only discussed by one of the 40 papers, and even the "most popular" descriptor only mentioned in five articles; it will be interesting to see how this picture develops in the complete review.

5. Discussion

The discussion is structured around the research questions that we identified in the introduction.

a. How do authors define the "sustainable lean" overlap?

17 articles do not define the sustainable lean overlap in any way; the descriptions of those that do are summarised below in Table 7, which shows again that although the theme of waste reduction in both lean and sustainability is most

commonly identified, the descriptions of overlaps are diverse and scattered. Particularly interesting were the suggestion that companies may become leaner as a side-effect of “going green”, a reversal of the more common statement of the green “side-effects” of lean; and that green tools such as CSR can benefit from the application of lean tools to make them more efficient.

Table 7 – Number of articles referring to sustainable lean overlap descriptors

Overlap descriptor(s)	Number of articles citing
Both lean and sustainability are about reducing waste	5
Opportunity to generate better solutions by considering lean and sustainability	4
Both are about seeking improvement/CI; lean can harm workforce; lean has no focus on ethics/safety/societal risks	3
Resource use/doing more with less; green is a side effect of lean; both lean and sustainability require employee empowerment; Lean tools can be adapted for green improvement	2
Consider both together to avoid interference or silos; both are about efficiency; performance measurement is necessary for both; accidents are wasteful; lean is a side effect of green; lean improves safety; lean has no focus on environmental risk; green tools can be "leaned"	1

b. What theories are used in sustainable lean papers?

Only four of the articles specifically mentioned use of theory of any kind as the basis for their investigations. Mefford [15] mentions that he applied marketing, finance and production theories, and Repenning and Sterman [16] used system dynamics, and improvement paradox. Rothenberg’s [17] paper is based on theory building, but institutional theory is mentioned in the findings. Longoni, Pagel et al [18] used "stakeholder theory and the concept of socio-technical systems and the service profit chain." Finally, Ratner, Bojesen and Bramming [19] do not mention any theoretical lens per se but use Italo Calvino's book “Invisible Cities”[20] as the basis for their literary abstraction/ hyperbolic social epistemology research method.

c. What motivations do we know of for organisations to adopt “sustainable lean” methods?

17 of the 40 papers do not cite any reasons to integrate lean with sustainability or any of its component parts (e.g. environmental, societal or workforce health and safety impacts). The 23 who do state reasons to integrate can be summarised as in table 8 below -

Table 8 – Number of articles referring to motivations for adoption of “sustainable lean” methods

Motivation descriptor(s)	Number of articles citing
Gain better solutions - green/social	14
Gain business, customer or shareholder benefits	10
Prevent silo thinking or interfering solutions; lean is a mature improvement system; gain better solutions - lean	2
Lean and green are both customer needs; lean and green are complementary and/or synergistic; To avoid green or social issues with lean; Running two systems in parallel is wasteful	1

We see that there is less diversity in this table, as the articles’ findings were easier to group; most fell into the categories of suggesting that integration of lean and sustainability (or one of its elements) would result in better environmental, social, business, customer or shareholder results. However we have a further 7 motivations that have seen little representation within this group of papers and might provide grounds for further research.

d. What gaps and opportunities for further work have been identified and remain unfilled?

29 of the papers had no suggestion for further work; the suggestions provided by the other 12 are summarised in table 11 below

Suggestion for further work	Articles citing
More empirical testing of this theory	4 [21-24]
More research in this field	3 [25-27]
Expand research into other sectors	3 [26, 28]
Integration of further fields	1 [29]
More definitions	1 [30]
Theoretical application in research; Integration of siloed knowledge; Systems approach; Applied metrics	1 [31]

6. Conclusion

The most obvious need for future work is to complete the review of the remaining papers, and also to carry out the “snowballing” technique to add rigour to the literature search method. These authors intend to carry out this work imminently. After the first phase of the search we found only 143 articles relating in any way to lean and sustainability; if the patterns seen in the 50 papers reviewed in depth are

repeated throughout, we will see only around 35 papers that link sustainability and lean and more than 30 might be purely opinion pieces. This supports the stated need by four of the papers reviewed for further research in the field and in particular for more empirical research.

We found that definitions for sustainability and for the overlap between lean and sustainability were quite diverse, perhaps indicative of the lack of maturity of these fields. Agreement on definitions that are useful in decision making would be beneficial.

There was greater agreement on motivators for integrating lean and sustainability, but seven fields were identified that were not widely discussed, if they are similarly unrepresented in the remaining papers these could represent a further opportunity for future work.

Only four papers were found that mentioned use of any kind of theoretical lens, so there are opportunities to consider this field through resource-based and natural-resource-based views of the firm, for example.

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