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Review

Lean manufacturing and sustainable performance: Trends and future challenges

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A B S T R A C T

Lean manufacturing has proven its positive effects on operational and economic performance in multiple cases. However, growing consciousness regarding sustainability and the Triple Bottom Line approach requires an integral performance based on three main goals: economic growth, environmental preservation, and social responsibility. Given the relevance that lean manufacturing has acquired, it is important to understand its effects on sustainability. Thus, this paper presents a literature review, discussing the most relevant findings of research in this sphere, and identifying current trends concerning the effect of lean manufacturing on sustainable performance. A total of 69 papers were reviewed, following a five-step synthesis methodology. Common and contrasting results were categorized according to each pillar of the triple bottom line, which allowed for the identification of not only growing research trends, but also of knowledge gaps. Unlike previous literature reviews, this study approaches lean manufacturing's effect on performance from a multidimensional point of view, accounting for all three triple bottom line pillars. It contributes on the identification of the main current research trends, which favors branches: one which supports complementary interactions between lean manufacturing and all three pillars of the triple bottom line, and the other, which evidences trade-offs among them. According to the results of the review, knowledge gaps on the matter remain, which require further research.

Contents

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1. Introduction

Since "The Machine that Changed the World" (Womack et al., 1990) was published, lean manufacturing (LM) has been recognized as a world-class manufacturing and management philosophy. Since then, several well-known authors have studied the different sets of tools comprising LM and their effect on performance, mainly from operational or economic perspectives (i.e. profit, cost, quality, delivery, etc.) (Negrão et al., 2017). Nevertheless, nowadays, there is a need to consider performance from a multidimensional point of view that also accounts for environmental and social impacts (Seuring et al., 2008).

As world population grows to an expected 9 billion people by 2050, and nonrenewable resources are more difficult and expensive to obtain every day, companies, governments and organizations need to embrace sustainability as a top priority. However, this is easier said than done. In spite of the wake-up call generated by 1987's "Brundtland Report" from the UN World Commission for Environment and Development (WCED, 1987), at least until the end of the 20th century, evidence suggests that many companies continued to relegate environmental protection and social responsibility to positions below economic performance (Pagell and Shevchenko, 2014). Although alternatives for the achievement of sustainable development (especially in the manufacturing industry) have emerged in recent years, there are still concerns about their long-term effectiveness and worldwide scalability, according to the World Business Council for Sustainable Development (WBCSD, 2011).

Elkington (1994, 1998) proposed a framework called the "Triple Bottom Line" (TBL), urging companies and organizations to measure their performance using a multidimensional perspective that integrates not only the traditional indexes such as profit, return on investment or share value, but also to include environmental and social aspects. The TBL accounts for three pillars (economic, environmental and social) as the base of successful sustainable development, and thus can be used as a metric for performance measurement in organizations. However, there is no universal standard for calculation of sustainable (or TBL) performance (Helleno et al., 2017; Slaper and Hall, 2011), making it difficult for companies to evaluate the impact of their policies and strategies, or to compare themselves with others.

In today's globalized market, consumers often set their own standards, and prices are determined by the market. To cope with this situation and increase competitiveness, manufacturing industries need to deploy several strategies. Lean manufacturing emerges as an advanced manufacturing strategy to provide productivity improvement, quality maximization, and waste elimination (Resta et al., 2016). However, there is growing pressure from stakeholders involved in the entire value chain, demanding that this continuous quest for efficiency and competitiveness doesn't come at the expense or detriment of the environment or the social conditions of citizens (Gupta, 2016; Martínez León and Calvo-Amodio, 2017; Sajan et al., 2017).

In spite of growing interest in research related to LM effects on performance, studies linking LM and sustainability remain scarce (Azevedo et al., 2012; Kowang et al., 2016; Resta et al., 2017). Therefore, the objective of this paper is to conduct a systematic literature review, highlighting the relationship between LM and sustainable performance (or TBL performance). The results are analyzed, discussed and categorized according to the identified trends on this topic, allowing for the identification of several knowledge gaps. Findings provide guidance for future lines of research on the subject.

The literature review was performed with data collected from the most highly renowned P&OM publications, and databases which gather them. Previous related literature reviews were used as starting points, when available. Relevant literature was cross-referenced to pinpoint seminal works, and thematic synthesis was used to group the results following the method proposed by Garza-Reyes (2015). Also, My Tree of Science (Robledo et al., 2014), a computational tool based on networks theory, and oriented to create citation chains from search equations, was employed. As shown in Table 1, previous literature reviews have identified different relationships between LM and performance, usually focused either on operational/financial performance or environmental performance alone.

Of the previous literature reviews considered, only three account for all three pillars of TBL sustainability. Martínez-Jurado and Moyano-Fuentes (2014) addressed the supply chain management perspective, linking this concept with LM practices. They conclude that further research is required regarding the interrelationships between LM and the three dimensions of sustainable performance, especially the social pillar, as their study covers mostly environmental sustainability, and the economic dimension from a sustained performance over time perspective (Martínez León and Calvo-Amodio, 2017). A second review carried out by Cherrafi et al. (2016), presents a brief account of benefits derived from LM, six sigma, and sustainability practices integration. Environmental and social benefits are considered in this review, but as the authors noted "*The negative effects of the integration of lean/six sigma and sustainability still have to be explored. By understanding such effects, it will be possible to investigate how they can be ameliorated so that a compromise between business, environmental and social performance can be made*" (Cherrafi et al., 2016). Finally, Hartini and Ciptomulyono (2015) present a brief account of positive impacts in operational, environmental, and social performance, derived from the interaction between LM and sustainable manufacturing practices. However, their work is limited to listing the results of literature review, without extracting possible explanations for those outcomes.

The current review presents a novel contribution to the literature by approaching LM effects on performance (both positive and negative) from a multidimensional point of view, using the TBL perspective. It accounts for LM's operational (OP), environmental (EP) and social performance (SP) outcomes, as noted in the literature. Previous reviews have listed both the positive and negative effects of LM in operational performance. This literature review goes further, so as to extract possible explanations from published articles for said contrasting results, and also considers both the positive and negative effects of LM on EP and SP (these topics are scarcely addressed in existing reviews). Finally, it analyzes the interactions of all three performance dimensions from a comprehensive "sustainable performance" perspective, which has not yet been thoroughly discussed in previous reviews. Therefore, in contrast to the other reviews presented in Table 1, special emphasis was placed on the identification of those contrasting sustainability effects which resulted from the implementation of LM practices, as well as the explanations provided for said outcomes.

Table 1
Lean manufacturing literature reviews.

Author	Main contribution	Performance Effect[a]		
		OP	EP	SP
Ben Ruben et al. (2018)	Reviews lean six sigma (LSS) literature focused on environmental outcomes, and draws an implementation framework combining LSS and environmental tools		6. X	
Danese et al. (2018)	Analyzes the effects of lean manufacturing in different technical outcomes (including operational performance) and social outcomes	X		X
Negrão et al. (2017)	Provide explanations for some studies showing the negative impacts of LM in OP, based on demand variability, organizational culture, and difficulties in long-term gains measurement	X	X	
Arroyo and Gonzalez (2016)	Define environmental and social wastes derived from lean principles in the construction industry		X	X
Cherrafi et al. (2016)	Propose model for the integration of lean, six sigma and sustainability	X	X	X
Gupta et al. (2016)	Extent and limitations of lean manufacturing principles implementation in service industry	X		
Hallam and Contreras (2016)	Integrate lean and green management into a single operation model has proven difficult, as both philosophies tend to be implemented independently		X	
Hartini and Ciptomulyono (2015)	Positive impacts of lean and sustainable manufacturing in TBL performance.	X	X	X
Garza-Reyes (2015)	Results relating lean and green practices implementation differ in literature. Some studies show interdependency between both practices, while others point to different effects on performance		X	
Gobinath et al. (2015)	Barriers and problems faced in lean implementation: lack of culture, knowledge, and planning. Short-term expectations by managers also cause failed implementation	X		
Yusup et al. (2015)	Propose a concept for lean manufacturing implementation through four stages: planning and product development, production planning and scheduling, manufacturing processes, and functional and visual inspection	X		
Bhamu et al. (2014)	Present different LM definitions found in literature and the main contributions of previous LM related research	X		X
Jasti and Kodali (2014)	Identify the main research streams in lean production, lean product development, lean management, lean procurement, lean distribution and lean enterprise	X		
Martínez-Jurado and Moyano-Fuentes (2014)	Identify two major trends in research literature, linking lean management and supply chain management with sustainability	X	X	X
Singh and Ahuja (2012)	Interactions and relationships between TPM, TQM, and operational performance	X		
Stone (2012)	Present the timeline of LM literature evolution over the past four decades. Proposes five phases of lean evolution: discovery (1970–1990), dissemination (1991–1996), implementation (1997–2000), enterprise (2001–2005), and performance (2006–2009)	X		
Mollenkopf et al. (2010)	Intersections, drivers, and barriers of simultaneous application of green, lean, and global supply chain strategies	X	X	
Papadopoulou and Özbayrak (2005)	First comprehensive LM literature review, presenting the evolution of lean, along with several misconceptions of practices and concepts to date	X		X

[a] **OP:** Operational performance. **EP:** Environmental performance. **SP**: Social performance.

This study presents the current state of research of LM impact on performance from a multidimensional point of view, covering operational/economic, environmental and social perspectives, where they have been previously studied in the literature. Although there are investigations, including some LM and sustainability relationships (Bergenwall et al., 2012; Chiarini, 2014; Martínez-Jurado and Moyano-Fuentes, 2014; Piercy and Rich, 2015; Vinodh et al., 2016), we have concluded that current LM research still falls short of proper identification, proof, and more importantly, management of the issues regarding its impact on long-term sustainability.

It can be concluded that most of the empirical evidence available from past research points to a positive LM – OP interaction (in most cases), while results relating to the effect of LM on EP show less consensus. Regarding the impact of LM on SP, contributions are still scarce, as are those embracing its holistic effect on the three pillars of TBL. One important contribution of this investigation relies on the identification of two major conceptual trends, regarding the effect of LM on sustainable performance. The first trend presents a win-win interaction between all three TBL pillars, with LM positively affecting each of them, and prompting cumulative performance gains. The second trend points to trade-offs between all TBL pillars, or at least between two of them, when LM demands resources. Therefore, in order to increase performance in one dimension, at least one of the others is negatively affected. Although partial evidence is presented to support each trend, a comprehensive explanation is not yet conclusive in the most recent literature. Consequently, this paper contributes to lay the groundwork for future lines of research relating to LM and sustainability, which allow for the clearing of yet unsettled conceptual and theoretical dilemmas in the field.

This paper is structured as follows: research questions and the methodology are presented in Section 2. In Section 3 the main findings and discussion are addressed. Section 4 provides insights for potential future research on the topic, and finally, relevant conclusions are presented in Section 5.

2. Research questions and methodology

2.1. Research questions

There is a great deal of empirical evidence linking the effect of LM to operational and economic performance (Chavez et al., 2015; Shah and Ward, 2003; Singh and Sharma, 2009), as well as evidence supporting the idea that "Lean is Green" (Bergmiller and Mccright, 2009; Yang et al., 2010). However, several authors claim that such evidence is only partially true (Belekoukias et al., 2014; Zhu and Sarkis, 2004), as most studies present only a "picture" of the current relationship between the degree of LM implementation and the specific performance measures applied (Machuca et al., 2011). Further, concerns raise regarding the lack of studies which investigate the relationships between LM and sustainability (Azevedo et al., 2012; Hartini and Ciptomulyono, 2015; Resta et al., 2017; Sajan et al., 2017).

Unsolved questions about sustainable performance, in addition to the interrelationship between the dimensions of the TBL concept and the way in which LM affects them, have led to various points of view. Ocampo and Estanislao-Clark (2014) sustain that there are two conceptual streams. The first suggests the existence of trade-offs among the three dimensions of sustainability (economic, environmental, and social) where improving one dimension can be detrimental to the others. The second view argues that there is a positive interaction between all dimensions, and so, EP improvement positively affects economic performance (and vice versa). However, evidence linking those mainstreams with SP is scarce (Lankoski, 2009).

Depending on the way in which they are implemented, LM strategies can present pleasing results, which tend to deteriorate in the long-term (Čiarnienė and Vienažindienė, 2014; Maginnis et al., 2017). This can be explained by two main factors. On one hand, waste reduction strategies tend to produce immediate and noticeable results when applied in companies where waste has not been systematically confronted previously (Pham and Thomas, 2005). As a result, a proper atmosphere is created for continuous improvement. When the most evident and critical problems have been eliminated, that atmosphere quickly deteriorates (Nordin and Belal, 2017), as from a LM perspective, the work to be done now focuses on a disparate series of small problems, which are sometimes difficult to identify (Ahmad et al., 2004; New, 2007). The elimination of ever-smaller problems produces ever-smaller gains in performance, to the point where the cost of handling those problems can exceed the benefits. Fig. 1 shows the relationship between gains in performance vs. costs incurred for their achievement. It becomes clear how, at a certain point, the marginal cost outweighs the marginal gain in efficiency.

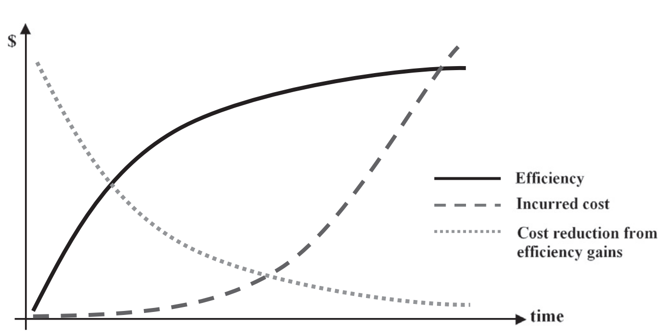

Fig. 1. Efficiency gain vs. incurred cost.

On the other hand, strategies focused exclusively on cost reduction have no other option but to seek cost reduction in critical processes, once cutbacks from the most significant wastes have been made. At that point, such practices can generate a negative impact on other performance dimensions, such as employee satisfaction, due to work placement uncertainty, or a shortage in available resources for investment in "green" and social initiatives.

Based on the above, the research questions that this paper expects to address are structured as follows:

- To what extent has the relationship between LM and sustainable performance been previously studied?
- Are the effects of LM on each of the TBL dimensions well identified and supported?
- What are the current trends in LM-sustainability research?

2.2. Methodology

In order to contribute to the breadth of knowledge in the field, and based on the aforementioned research questions, a systematic literature review was performed. To guarantee objectivity, reproducibility, and transparency, the applied methodology was based on Garza-Reyes' (2015) contribution, which proposed the following five phases:

1. Question formulation: this could be the least systematic phase of the method, as it relies on multiple inputs which can range from the conclusions and recommendations of previous research to the researcher's own experience and intuition.
2. Definition of search strings and databases: online globalization of knowledge has facilitated the gathering of relevant information about specific topics in databases, collecting papers and publications from multiple well-known sources around the globe. This gives the researcher access to almost unlimited material, but tasks them with the responsibility of properly identifying databases which gather the most pertinent information in their field of research.
3. Material review and evaluation: search strings can return either relevant or irrelevant material, and its evaluation becomes a time intensive task for the researcher, as a quick overview of the contents determines whether it is worthy of being studied in depth, or whether it should be dismissed, as it doesn't contribute to the resolution of the research questions.
4. Analysis and synthesis: after relevant material has been selected, an in-depth study of each paper must be performed. As a result, similarities, general consensuses, conclusions, and other trends are identified. Discrepancies in literature must also be pointed out, as well as inconsistencies and contradictions. Those elements can point to areas in which additional research is required. To collect the information and present it in an organized fashion, thematic synthesis and conceptual maps were used, based on Ceulemans et al.'s (2015) approach.
5. Conclusions and recommendations for further research: a properly conducted systematic literature review most likely points to one of the three following outcomes: first, the conclusion that research questions have already been answered with an acceptable level of consensus, and that there is strong evidence to support this. Second, that there is a lack of theoretical background for the research questions, and therefore exploratory research is required to provide the necessary theoretical developments. Third, that there are proposed

theories about the research questions, but not enough empirical evidence or general agreement to prove them, thus requiring more confirmatory or empirical research.

2.3. Search strings and database selection

Through exploration of electronic databases, gathered knowledge can be found in very specific search engines, which provide easy access to researchers and academics. The databases consulted were Scopus (www.scopus.com) from Elsevier B.V., and ISI Web of Science (www.wokinfo.com) from Thomson-Reuters. These electronic databases have the largest indexes of industrial engineering, manufacturing, operations research, and sustainable development material, amongst other related topics. All major journals and publications with high impact factors in fields related to the present research topics are indexed in the consulted databases. My Tree of Science (ToS) (tos.manizales.unal.edu.co) was also employed. This tool uses algorithms based on network theory to create citation chains from the results of a given search string, and also to order them (Robledo et al., 2014). Results are organized in a tree scheme, where the roots represent the seminal studies from which the research field emerged; branches are the different research trends, some of them already “closed” and others still open. Finally, the leaves represent the most recent contributions to each branch.

The first search string included only the specific terms directly related to the present investigation's two main research topics (see Table 2), including other terms usually employed by authors to refer to LM, or forms of LM, such as Just in Time (JIT), or Toyota Production System (TPS). As few papers were found, the results from the first string proved that this is a relatively new research trend. In consequence, to broaden the reach of topics, a second search string was applied. Both search strings were applied only to the title, abstract, and keywords fields.

3. Results and discussion

3.1. Results data

A total of 679 papers resulted from the search strings, 137 of which were present both in Scopus and Web of Science. For sorting purposes, both papers published in peer reviewed journals and conference proceedings were considered. Papers were reviewed in English, Spanish, Italian, French and Portuguese. Papers written in other languages were not considered in this review.

As not all of the resulting papers were directly related to the research topic, or contributed to answers for the specific research questions proposed in this investigation, based on a review of abstracts and titles, a preliminary selection of all the available material resulting from the search strings was performed. This initial review was conducted based on three categories (see Table 3): directly related, indirectly related, and non-related. Directly related papers were later carefully and fully reviewed, since they are the core of the present investigation. Indirectly related articles address one of the research topics (i.e. LM or sustainability), but do not correlate them both, and so were not considered for this review.

It's also important to mention that, when papers containing follow-ups to previous investigations, updates, or new results by the same authors were found, only the most recent publication was included. Fig. 2 shows the evolution of the number of publications by year, from directly related category papers. It is clear how, in the past five years, published papers have almost tripled, showing a growing interest from the scientific and academic communities in this field of study.

3.1.1. Classification of findings

As shown in Fig. 3, important information can be extracted from a thorough review of the selected articles. Research type shows that most of the work has been done via survey/empirical studies, as the data from large scale surveys like the HPM (High Performance Manufacture), and IMSS (International Manufacturing Strategy Survey), has become more widespread and reliable. Those data sources represent a useful resource, from which researchers all over the world have drawn important conclusions. These will be discussed in Section 3.2.

The employed methods rely mostly on multivariate statistical tools, such as SEM (Structural Equation Modeling) which allow more complex cause-effect relationships to be identified among the different variables (or constructs) which comprise the levels of LM implementation and performance measures, mostly in the operational, economic, and environmental dimensions. Regression models are also commonly used, as they provide a less complex mathematic approach when there are fewer variables involved. They are also more common to longitudinal studies, while SEM results more common in cross sectional studies.

The industry/sector part of Fig. 3 shows that most of the studies were carried out in the automotive industry, which can be explained by the close relationship between the industrial sector and the origins of LM in the TPS (Toyota Production System) (Womack et al., 1990; Liker, 2004). After the nineties, the adoption of several LM practices became a must for western car manufacturers (Bergenwall et al., 2012; Büyüközkan et al., 2015; Womack et al., 1990), for the achievement of increased competitiveness through processes efficiency, waste reduction, and flexibility improvements.

However, in many cases, western manufacturers have failed to produce the same outcomes as their Japanese counterparts. The reasons behind those failures are of interest for academics around the world, which is reflected by an almost even distribution of research around the globe. It is important to highlight that the geographical application metric in Fig. 3 shows where the data for a given paper was collected, independent of where it was published, or the origin of the authors.

The bottom part metrics from Fig. 3 are of even more interest. The main focus shows that most articles are centered on either the LM or sustainability topics individually, but tend to cover partial relationships in the other field, even when it isn't stated in the aim of the investigation. On the other hand, only 35% of the reviewed papers state relationships between LM and sustainability as the aim of the study. However, some of the articles which claim to analyze

Table 2
Systematic literature review search strings.

String	LM keywords		Sustainability keywords
String 1	“lean manufacturing” OR JIT OR TPS	AND	Sustainability OR “triple bottom line” OR TBL
String 2	"lean manufacturing" OR "manufacturing practices" OR TPS OR JIT	AND	“operational performance” OR “operational efficiency” OR sustainability OR “sustainable performance” OR "green performance" OR “environmental performance” OR TBL OR "triple bottom line" OR “social performance”

Table 3
Classification of search results.

Classification	Number of publications	Description
Directly related	69	Articles directly relating LM to one or more performance measures, or proposing suitable sustainability performance assessment methods
Indirectly related	160	Papers that approach one of the research topics (LM, sustainability), but lack a significant connection to the others.
Unrelated	450	Papers about different topics, not pertinent to the proposed investigation

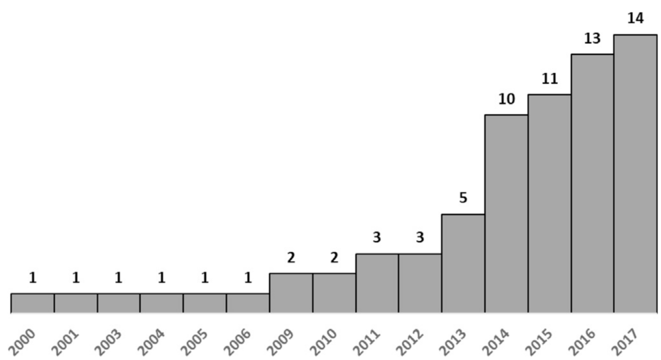

Fig. 2. Time evolution of published papers relating LM & Sustainability.

sustainability effects account only for environmental outcomes, as it remains common in the literature for sustainability to not be supported by all TBL pillars. For this reason, social performance is often left to the side.

The aforementioned point is supported by the performance impacts measured in the reviewed papers. As expected, most research in the field covers the operational or economic measurements of performance, while 40% of it also accounts for environmental outcomes. In general, the social outcomes of manufacturing strategies (including LM) are still less researched topics, as noted by Lankoski (2009), with only 21% of the reviewed papers measuring some dimension of social performance. Finally, although 29% of papers claim to measure sustainable performance, some of them consider "sustainability" to be only environmental effects.

3.1.2. Most cited works

In order to pinpoint the seminal studies which have marked research paths in recent years in both fields of study (LM and sustainability), a cross referencing check was performed, taking into account all 69 papers. Through the application of My Tree of Science, the most cited papers and books were also identified. Fig. 4 shows the number of citations found for the forty most cited works.

"The Machine that Changed the World" (Womack et al., 1990), presented to western world the basic principles of LM from the experience obtained from the TPS and other similar production philosophies. This contribution proposed pathways for LM implementation on a worldwide scale, and concluded that it is in the manufacturing industry's best interest that LM is globally adopted as soon as possible. Shah and Ward's (2003) paper can be considered the second landmark, as they "operationalized" LM as groups (bundles) of practices and tools, which had previously been studied separately. Through a detailed examination of each individual practice, they proposed four bundles, which have been used vastly in the literature ever since, providing empirical evidence of the impact of each bundle on OP. The four proposed bundles are: Just in Time (JIT), Human Resource Management (HRM), Total Quality Management (TQM), and Total Productive Maintenance (TPM).

The third landmark is related to sustainability and sustainable

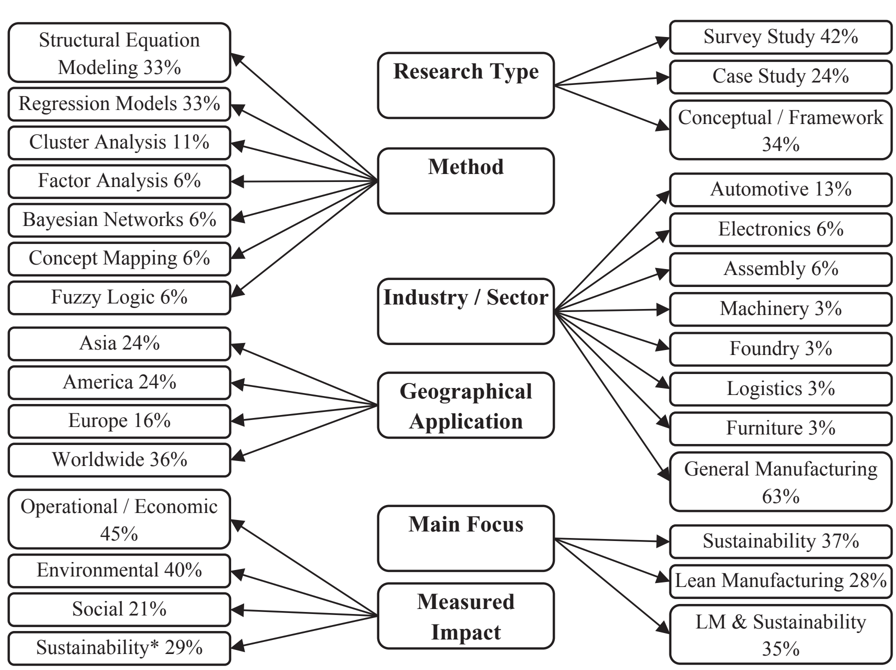

Fig. 3. Classification of reviewed papers.

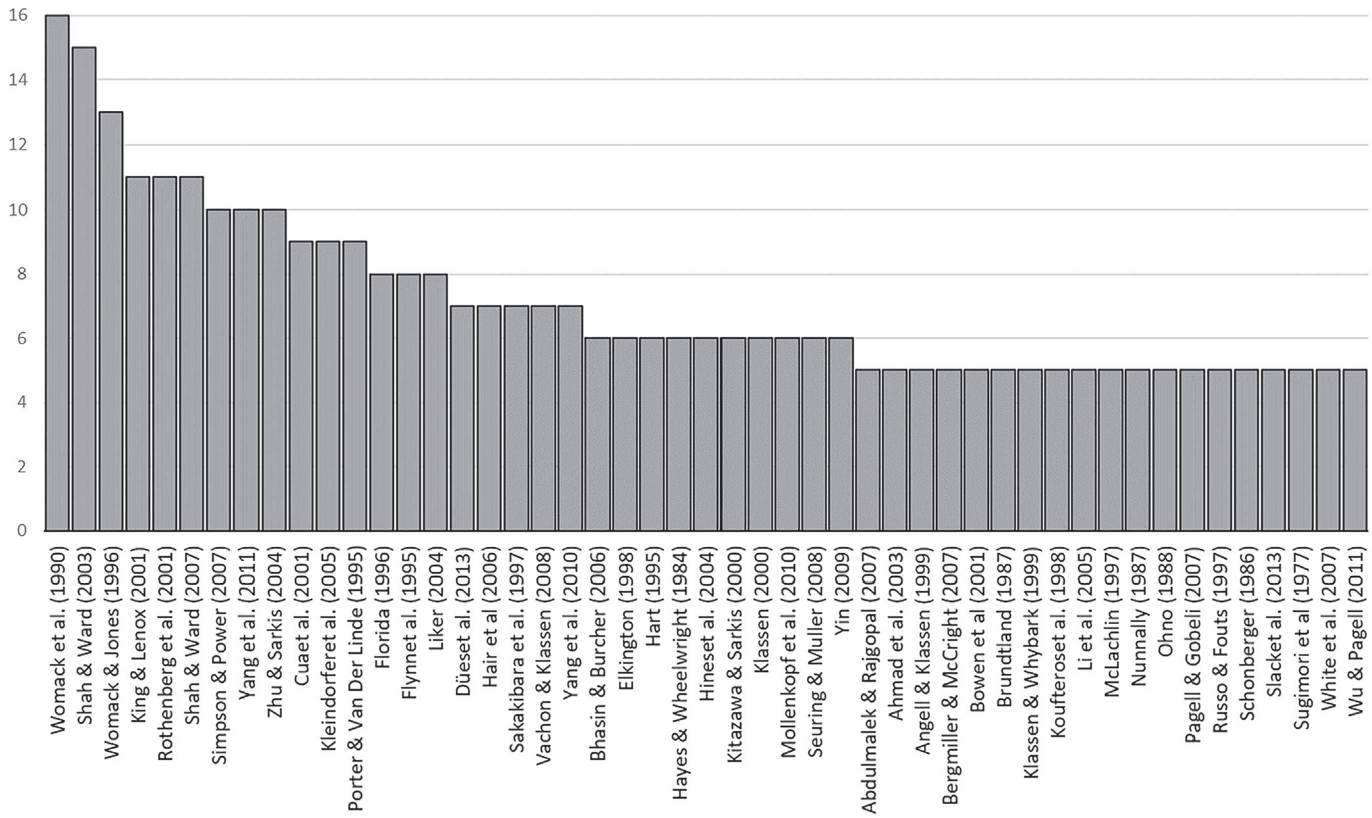

Fig. 4. Most cited papers and books among reviewed articles.

performance. "Partnerships from Cannibals with Forks: The Triple Bottom Line of 21st-Century Business" (Elkington, 1998) capitalized on growing interest in sustainability in the late 20th century by sending a strong alert to companies, governments, and organizations stating that development could not continue to be based on economic performance alone. Instead, Elkington proposed the concept of the TBL (Triple Bottom Line) as a way to measure and focus development on three pillars: economic, environmental, and social.

Even in 1998, he stated that "*future market success will often depend on an individual company's (or entire value chain's) ability to simultaneously satisfy not just the traditional bottom line of profitability but also two emergent bottom lines; one focusing on the environmental quality, the other on social justice*" (Elkington, 1998). By the new millennium, the public's growing concern about sustainability acknowledged Elkington's previous statements. However, as he later stated "*the TBL agenda as most people would currently understand it is only the beginning*" (Elkington, 2004).

3.2. Findings and discussion

3.2.1. Lean manufacturing and operational performance

Although some studies, including those of Chavez et al. (2015) and Büyüközkan et al. (2015), account for operational and financial (or economic) performance as separate dimensions, in this document the TBL approach will be employed, which means that financial or economic outcomes are considered to be part of a company's business performance (Slaper and Hall, 2011). Business performance is affected by various aspects, which may be either internal or external to a company (Ghalehkhondabi, 2017). In manufacturing operations, it may be said that business performance is a result of operational (or manufacturing) performance, market performance, and financial performance (Avella and Vázquez-Bustelo, 2010; Busse, 2016; Büyüközkan et al., 2015).

Studies from the literature review have provided evidence which indicates that strong performance in operational measures, such as cost, quality, delivery, lead time, or flexibility can have a positive effect on business performance dimensions (Arcidiacono et al., 2016; Avella and Vázquez-Bustelo, 2010; Martínez León and Calvo-Amodio, 2017). However, as previously mentioned, financial and market variables (some of which are external to the company) also have a significant effect on a company's overall economic performance. Therefore, operational performance was considered to be the entire set of measures which contribute to business performance, including financial and market performance, unless specifically categorized as a separate dimension by authors, as in the LM – OP line of seminal research, which includes the works of Shah and Ward (2003) and Dal Pont et al. (2009).

As expected, the LM – OP relationship was the first to be studied, in investigations dating back to the eighties. However, prior to Shah and Ward (2003) only the effects of single practices or lean principles were studied, and not LM as a package of interdependent practices, which together comprise a LM strategy or philosophy. Generally, empirical evidence supports the notion that LM implementation contributes, to some degree, to the enhancement of OP in several scenarios (Chavez et al., 2015; Negrão et al., 2017). Successful implementation of synergistic LM practices can account for an OP increase of up to 23% (Shah and Ward, 2003), when measuring shop floor dimensions such as quality, lead time, unit cost, and flexibility. Büyüközkan et al. (2015) found that OP measures tend to be positively affected by up to 16% if a company reaches 100% effective use of LM. Performance can even increase up to 20% when financial variables are considered in the performance measure. However, it can also drop to just 13% with the average level of LM implementation found in companies.

While most authors agree that LM practices are interrelated (Bortolotti et al., 2012; Čiarnienė and Vienažindienė, 2014; Shah and Ward, 2003), and their successful implementation depends on the achievement some degree of balance between them, some sets of practices appear more often as the main drivers of OP gains. For instance, Belekoukias et al. (2014) found that quality is mostly affected by JIT practices, claiming that as JIT reduces inventory levels, quality problems are more likely to be exposed, and require immediate attention. In their study, JIT also had the highest impact of all LM practices on speed, as well as dependability (dimensions related to on-time deliveries), and a significant positive effect on cost and flexibility. This positive JIT – OP relationship is backed by several other studies (Bortolotti et al., 2015; Dal Pont et al., 2009; Ketokivi and Schroeder, 2004; Rahman et al., 2010; Shah and Ward, 2003; Zhao et al., 2014). There is also an identifiable pattern linking TQM implementation to OP improvement.

In spite of evidence pointing to the positive effect of LM implementation on OP, there are some contributions which support the contrary, or which point towards other attenuating elements of that relationship (Bergenwall et al., 2012; Čiarnienė and Vienažindienė, 2014; Espejo Alarcón and Moyano Fuentes, 2007; Negrão et al., 2017; Pham et al., 2011; Taggart and Kienhöfer, 2013). Those findings can be explained from the contingency perspective, meaning that every company requires an individual approach from the manufacturing strategy perspective. Also, some authors claim that the LM-performance link is of such complexity that it is difficult to account for all the variables mediating on it (Chavez et al., 2015).

Other explanations provided to support the negative LM – OP relationship, claim that some organizations fail to see LM as a continuous process, which could explain good results when it is a novelty, and later falls in rank when compared to other projects or priorities (Čiarnienė and Vienažindienė, 2014). Also, traditional LM practices are good at driving efficiency and lowering costs (waste minimization). However not all of them can be considered "fitness" practices, which maintain sustained growth in changing environments. Along the same lines, Pham and Thomas (2011) assert that "*the success of Lean in companies often mirrors the classic change curve. Improvements in productivity after an intervention are soon followed by a steady decline to baseline, and sometimes even below baseline levels*".

This happens as people return to their previous ways of working, or the focus is shifted to other priorities. Čiarnienė and Vienažindienė (2014) claim that only about 10% of companies achieve successful implementation of LM practices. Also, empirical studies reveal a high rate of abandonment of LM implementation in the first three years (Resta et al., 2017). According to the analyzed literature, three basic factors are proposed as determinant of successful OP improvement (or detriment) through LM implementation:

1. Human factors: Čiarnienė and Vienažindienė (2014) proposes two types of barriers which lay the groundwork for limited LM implementation success. The first few are people-related: certain issues, such as attitude, resistance to change, lack of knowledge about LM, and poor communication were identified. The second type refers to organizational barriers, for example culture, lack of resources for implementation, a weak alignment between improvement programs and the defined strategy, scarce data collection and performance measures, and the tendency to return to the old ways of working. These barriers are also consistent with those listed by Ben Ruben et al. (2018). While Alhuraish et al. (2017) do not make a differentiation between people-related and organizational barriers, they do account for most of them in their "critical success factors" for LM. This is complemented by evidence of unionized plants being less prone to implementation of human-related practices, such as standardized methods or cross functional training (Bergenwall et al., 2012; Shah and Ward, 2003).

   Both barriers are strongly related to human behavior, whether they reflect on individual or organizational conduct. This is reinforced by Longoni et al.''s (2013) findings which identified an adverse "snowball effect" when certain LM practices are forced into the workforce, without previously resolving human resource issues. These authors point out that pushing JIT and TQM onto workers untrained in LM, who are not conscious of how changes might benefit them in the long term, results in jeopardizing safety and shifting employees' focus away from quality. Human factors were also identified in some case studies as the cause of lack of success in LM implementation (Resta et al., 2016).
2. Context factors: contingency theories state that, since all organizations are different, there isn't a manufacturing strategy that can be applied universally. The same idea applies to LM and its practices, as evidence suggests that many underperforming or unsuccessful cases are related to contextual factors (Dal Pont et al., 2009; Espejo Alarcón and Moyano Fuentes, 2007; Rahman et al., 2010; Shah and Ward, 2003; Womack et al., 1990). LM principles originated in Japan (Womack et al., 1990), so clearly, cultural differences between Japanese companies and those around the world may prevent all LM practices or principles to be equally applicable (Nordin and Belal, 2017), or minimally assimilated in other countries (Danese et al., 2018).

   The influence of contextual factors has been documented since Shah and Ward (2003), who stated that "*organizational context, i.e. plant size, unionization and plant age, matters with regard to implementation of lean practices*". They found that, for example, larger plants were more prone to implementation of most LM practices, and this was latter supported by other investigations (Negrão et al., 2017). Along this line, Rahman et al. (2010), found that JIT has more impact on large enterprises, in contrast to other lean principles including waste minimization, which has more influence on small and medium-size enterprises' OP. More recent findings also point to LM being able to positively impact OP only in environments (productive and market) with a low level of technological turbulence (Chavez et al., 2015).
3. Sequence factors: using the analogy of crop cultivation, the terrain has to be prepared before planting the LM seed in order for it to grow properly, develop strong roots, and produce the expected fruits in the medium and long-term. Organizational culture has been known to play a major role in this process (as the fertile ground), with some companies struggling with ineffective LM practice implementation as a result of a hostile organizational environment (Negrão et al., 2017). Čiarnienė and Vienažindienė (2014) have found that the extent of the matter is such that an average company can take, at minimum, five years to fully implement a LM strategy.

   Culture aside, the reviewed literature has revealed that it is more likely to achieve positive effects on OP when practices are implemented in a given sequence, rather than concurrently, as people struggle to cope with a large number of changes, resources are often limited, and some practices support others. Practices related to the HRM bundle have been found to provide a good base structure, to prepare the organization for the subsequent implementation of other practices (Dal Pont et al., 2009), and it is recommended that they be introduced early. Belekoukias et al. (2014) also found that VSM (Value Stream Mapping) is necessary as one of the first steps when implementing LM, but companies must be aware that an incorrect or inaccurate VSM may lead to resources being allocated to the wrong priorities.

In a similar approach, Bortolotti et al. (2015) proposed a "sand-cone" model, in which some lean bundles are described as "fitness" bundles, thus providing the support needed for successful implementation of other practices, and their subsequent improvements in OP. The proposed fitness base practices are JIT and TQM. As the bases for these practices grow, the organizational structure surrounding LM not only becomes more robust and able to support other goal-oriented practices, but also becomes more capable of dealing with context variations which might affect quality, delivery, flexibility, or cost.

3.2.2. Lean manufacturing and environmental performance

While studies linking LM and OP were, in most cases, based on survey studies and statistical analysis, the reviewed literature on LM and EP relied mostly on case studies and frameworks (Domingo and Aguado, 2015; Galeazzo et al., 2014; Miller et al., 2010; Thanki et al., 2016; Torielli et al., 2011; Verrier et al., 2016; Vinodh et al., 2016). This may be explained, in part, by the difficulty of finding appropriate EP metrics that can be applied, and which are comparable, in different organizational contexts, in the way that quality, service, cost, and delivery apply generally to the manufacturing industry (Domingo and Aguado, 2015). The use of case studies has been common in manufacturing strategy research for many years. They are valuable, as proof of concept in certain scenarios, however they pose difficulties related to results generalization (Ketokivi and Schroeder, 2004).

One well-covered topic in recent LM literature explores the Lean-Green relationship, which in some cases, is closely related to EP. From this perspective, Garza-Reyes (2015) offers an important benchmark, by reviewing the literature on Lean-Green from 1997 to 2014. His findings show evidence of inconsistencies and contrasting results, with some pointing to reciprocal interdependencies between lean and green practices, and complementary effects between them, while others found that both practices differ in their essence, and so lead to different impacts on performance. Resta et al. (2016) emphasizes that, to avoid these contradictory results, LM has to be analyzed as a complete philosophy, rather than the EP impacts of some specific practices.

This is also supported by Galeazzo et al.'s (2014) and Resta et al.'s (2017) conclusions that the empirical evidence available of the LM effect on EP ranges from positive to negative results. Bergenwall et al. (2012) state that "*the findings are mixed.* Rothenberg et al. (2001) *suggest that there may be tradeoffs involved between lean production and environmental performance and other research suggests that lean production and environmental performance are complementary*". Garza-Reyes (2015) concludes that part of the problem resides in the fact that "*there is a shortage of lean and green research focused, particularly, on developing measurement methods or models for specific processes and industries*", and that "*the lack of clear and consistent conclusions from these studies may suggest that the research done until now to try to establish the effect of lean-green practices on different aspects of organizational performance is still limited and inconclusive*".

While Garza-Reyes (2015) sufficiently illustrates Lean-Green research trends and challenges, many of his reviewed works are excluded from the current review, as they do not match the criteria of accounting for more than one performance dimension (they focus exclusively on the environmental dimension). In consequence, more valuable information on the LM-EP and its contribution to sustainable performance can be extracted from other papers reviewed for this investigation.

An interesting trend emerges in the reviewed papers, which points to the EP gains achieved when LM is implemented as being side effects or unintended results which do not necessarily replicate in all LM implementations (Corbett and Klassen, 2006). This claim is supported by four relevant contributions: a) Torielli et al.'s (2011) findings which imply that lean practices alone do not necessarily produce environmental benefits; b) Bandehnezhad et al.'s (2012) conclusion regarding the negative environmental impact of some JIT associated practices, due to more frequent changeovers and the increase of delivery frequencies; c) Resta et al.'s (2016) "green spillovers", which mean that LM effects can lead to waste reduction and less energy and resources use; and d) Piercy and Rich's (2015) acknowledgement of past research, showing that "*environmental benefits have been seen as a by-product of lean operational improvement (*Florida, 1996*), what* Corbett and Klassen (2006) *term 'the law of unexpected side benefits'*".

In spite of this, there are also research results which point to a more direct, positive LM – EP relationship, and that even that relationship can have a positive influence on OP (Jabbour et al., 2013; Monge et al., 2013; Prasad et al., 2016; Thanki et al., 2016). Vinodh et al. (2011) propose that the LM waste minimization approach, should consider environmental waste (unnecessary or excessive usage of resources as well as substances released into the air, water, or onto the land that could harm human health or the environment) to be the ninth waste (eight being unused human potential, and the other seven classical manufacturing wastes, listed in Table 4), and therefore should be systematically reduced. They found that pull systems, associated with JIT, can result in less work in process product damage, 5S and cellular manufacturing can lead to less energy consumption (Bandehnezhad et al., 2012), and TPM can attend to spills and leakages immediately, thus preventing contamination.

A possible explanation for the results of LM – EP ranging from negative, to unexpected, to positive, is derived from other studies in the literature. Evidence suggests that, while the traditional LM approach is not directly oriented towards the improvement of environmental performance, it can be complemented with Green Manufacturing (GM) practices, which build upon existing capabilities derived from LM principles (waste minimization, continuous improvement, workforce training, and empowerment, for example). Nevertheless, lean practices are not necessarily green practices. Verrier et al. (2016) propose an interesting parallel between the seven green mudas and the traditional seven LM mudas, and how they interact with each other, as illustrated in Table 4.

Given the different natures of LM and GM practices, their effect on EP can also be diverse. It is most likely that LM practices alone will fail to provide a significant positive improvement in EP. However, when both practices are implemented concurrently, their effects can boost not only EP, but also OP, more than if they are implemented separately (Galeazzo et al., 2014; Miller et al., 2010). This is also complemented by Jabbour et al.''s (2013) study, which states that "the ability of the operations/manufacturing area to support environmental management tends to be greater when the company adopts lean manufacturing practices", meaning that changes in organizational culture achieved through LM implementation are fertile ground for practices focused on the environment, as they share similar principles (Miller et al., 2010; Verrier et al., 2016).

3.2.3. Lean manufacturing and social performance

Social Performance (SP) is the least studied in LM literature, and in fact, it is the least studied TBL outcome in all operations management literature (Besiou and Van Wassenhove, 2015; Cherrafi et al., 2016; Corbett and Klassen, 2006; Longoni et al., 2014; Resta et al., 2017). Social outcomes pose several challenges for research related to manufacturing and production strategies, since they are

Table 4
Lean and Green mudas.

Lean mudas	Green mudas	Interactions
Overproduction	Excessive power usage	Excessive power usage can be a result of almost all lean mudas, affected by overproduction, quality defects, excess inventory, inappropriate processing, and transportation.
Defects	Greenhouse gases	
Unnecessary movement	Eutrophication	
Unnecessary inventory	Pollution	
Inappropriate processing	Excessive resource usage	Excessive resource usage can be affected by defects, overproduction, excess inventory, and waiting.
Inappropriate transportation	Excessive water usage	
Waiting	Poor health and safety	

Own elaboration, based on: (Miller et al., 2010; Nujoom et al., 2017; Verrier et al., 2016; Vinodh et al., 2011).

characterized by a fair grade of complexity, due to conflicting goals from the various stakeholders (mainly organizations and communities). This creates uncertainty, divergence, and the need for trade-offs between short-term losses and long-term benefits (Besiou and Van Wassenhove, 2015).

In spite of scarce research on the matter, increasing pressure for companies to address all TBL pillars is raising concerns about the impact of LM (and other manufacturing strategies) on society (Besiou and Van Wassenhove, 2015; Resta et al., 2016), both the group of people directly related to the organization (i.e. the workforce), and the community indirectly affected by it. This situation leads to imminent trade-offs between social and environmental performance, and profits. The question that remains implicit is whether it is possible to achieve an optimal behavior, which balances both internal operational and economic results with societal outcomes. The answers are limited from the beginning, given that there is little consensus about an appropriate or desirable level of social responsibility that a company should strive to achieve (Besiou and Van Wassenhove, 2015). Metrics are either uncommon or incomparable (Slaper and Hall, 2011), making it difficult to assess SP. However, Pagell and Shevchenko (2014) claim that SP is an issue that research is able to overcome, as it is directly related to people's wellbeing, and measures already exist (although separately) in the form of worker's safety, long-term health, and even psychological safety.

One of a few studies, which directly focuses on LM effects on aspects that can be considered part of SP, was carried out by Longoni et al. (2013). They performed a multi case study to discover how LM practices implementation impacts aspects related to workers' health and safety. Their findings show that LM can do both harm and good, depending on how practices are implemented and interrelated, a conclusion shared by Resta et al. (2016). For example, the adoption of JIT requires HRM practices to develop the skills and desired level of worker involvement, prior to asking for lower lead times and less waste. Otherwise, it has harmful consequences in operational and safety performance. This is the same for TQM, as the technical system (the tools and practices involved, like SPC) has to deal with the social system (the workers) in order to succeed.

Longoni et al.''s (2013) findings are complemented both in their positive and negative implications. Verrier et al. (2016) consider poor health and safety to be a muda (waste), and therefore expect that a company with a strong LM philosophy should be eager to minimize these risks. On the other hand, the pursuit of standardization through LM, without the proper level of employee empowerment, can end in routine operation, which is often associated with a lack of improvement, slippage back to old ways of working, laxity, rule breakage, defiance, and even sabotage (Ketokivi and Schroeder, 2004). Resta et al. (2016), found that, in all cases, some initial opposition was present from workers dealing LM implementation, but positive results were usually achieved in the long term. Nevertheless, current studies still suffer from numerous limitations related to the appropriate measures and indexes, as well as the small samples considered (Longoni et al., 2013).

Another comprehensive research on the LM-SP relationship was performed by Distelhorst et al. (2017). They used data from more than 300 apparel factories located in developing countries, to test the effects of LM implementation on SP from two different conceptual approaches. First, that lean implementation should encourage companies to retain their "lean workforce", resulting in better terms of employment. Second, that lean management capabilities should lower the costs of social initiatives, and in general of complying with social standards.

Their results support that there is some degree of positive influence of LM in SP, but some noticeable caveats remain. On one hand, they proved that LM is associated with up to 15% improvement in labor standards compliance (Distelhorst et al., 2017), however, as must labor standards change from one country to another, a high degree of heterogeneity was found on the results, with India, Malaysia, Thailand and Vietnam presenting positive results, while in Sri Lanka, China, and other evaluated countries, the effect of LM on SP was not significant. On the other hand, improvements were found to be mostly related to wage and work hours compliance, since companies were willing to offer improved conditions to retain the training effort put into the "lean workforce", however, no effect was detected on health, safety, and environmental standards (Distelhorst et al., 2017), probably because they require structural changes and investments.

3.2.4. Sustainable performance

There are few studies related explicitly to the LM – Sustainable Performance (SSTP) relationship. However, they represent the closest approach to the state of the art in this field of study. On the other hand, most of the reviewed investigations which address important SSTP issues only marginally relate them to LM or some of its principles or practices. The present section presents the more general conclusions of the non-strictly LM-related papers, while relevant findings of the directly LM – SSTP related investigations are presented in Section 3.2.5.

The majority of papers reviewed in this section consist of frameworks, either for the development of strategies to account for sustainability in manufacturing and operations (Despeisse and Vladimirova, 2014; Kowang et al., 2016; Longoni et al., 2014; Longoni and Cagliano, 2015; Martínez León and Calvo-Amodio, 2017; Ocampo and Estanislao-Clark, 2014; Pham and Thomas, 2011), or presentation of SSTP metrics, and ways to assess the sustainability of a given organization or parts of its value chain (Gimenez et al., 2012; Gualandris et al., 2014; Ketokivi and Schroeder, 2004; Reich-Weiser et al., 2008). In both cases, it is important to consider that the concept of sustainability is approached from different perspectives in the literature. One perspective adheres to the TBL approach, accounting for some level of balance between the three pillars (economic, environmental, and social) while in other cases, sustainability is referred to as the ability of an organization to "sustain" itself in the long-term

(Nordin and Belal, 2017; Pham and Thomas, 2011; Reich-Weiser et al., 2008). This cannot only be related to economic, social and environmental drivers (Gualandris et al., 2014; Pagell and Wu, 2009), but also is related to sustained growth through time, from a purely financial point of view, which is a notion which arose almost half a century ago (Friedman, 1970) and is still accepted today in some cases (Kowang et al., 2016).

Practices oriented towards the improvement of sustainability can be applied to all links of the value chain (supply, manufacturing or sales). Thus, companies must account for the multidimensional nature of performance in order to properly understand how it is affected by different practices (Ketokivi and Schroeder, 2004). From this perspective, Despeisse and Vladimirova (2014) urge manufacturers to consider non-financial information (environmental and social impacts) in their decision-making processes. However, they acknowledge that this is rarely done, owing to the difficulties of qualitative benefit evaluation and the inconvenience of comparing those to short term economic benefits. This makes integration of sustainability into their day-to-day operation a struggle (Longoni and Cagliano, 2015). Said vision is shared by Ocampo and Estanislao-Clark (2014), as they claim that firms are often uncertain about investing in sustainable manufacturing practices, due to the "intangible" nature of their outcomes.

This difficulty of translating EP and SP into indexes, comparable in economic or financial terms to OP, creates a challenge for companies and managers, as they need to justify those initiatives to shareholders. Some social and environmental initiatives, like safety measures and pollution control mechanisms can increase manufacturing costs (or manufacturing time), thus having negative short-term effects on OP (Gimenez et al., 2012), and create the need to find better means to improve environmental and social performance (Gualandris et al., 2014; Ketokivi and Schroeder, 2004). As a way to achieve long-term business sustainability, Pham and Thomas (2011) propose the "Fit Manufacturing Framework" (FMF), which combines lean, agility, and sustainability principles to develop a more robust manufacturing strategy that is able to cope with constant changes in the market. However, in this framework, sustainability is defined as "*being able to attain long-term profitability in what is now an increasingly volatile and complex marketplace*", which does not necessarily imply acceptable environmental and social performance.

The FMF starts with business and manufacturing strategy, sales, financial, and knowledge development. Those items are called the core systems, and they create the basis for operational systems development, which comprises elements of lean, agility (linked mostly with flexibility), and sustainability (related not only to the strategy, but also to external factors that might affect the core system). Finally, business systems are developed on top of the other two, and comprise the technological aids, demand, and supply chain management, and the re-configurability of systems necessary in order to respond to the changing environment (Pham and Thomas, 2011). The FMF outputs should then reflect improved flexibility, improved efficiency, improved efficacy, increased OEE, higher productivity, mass customization capability, increased GVA, economic sustainability, reduced downtime, reduced lead-time, improved quality, reduced product cost, improved on-time delivery and increased stock turnovers. According to Pham and Thomas (2011), those elements should allow for long-term profitable sustainability. That however, is not necessarily supported by all three TBL pillars, as previously shown.

Longoni et al. (2014), and Longoni and Cagliano (2015) present a different approach to adopting sustainable performance drivers in organizations. In their first study, they suggest that some HRM practices can lay the foundation for sustainability, while acknowledging that more research is still required in regards to linking operational practices (which include LM) to social and environmental dimensions. Their findings show that HRM practices (training, involvement, and incentives) have a direct impact on SP, as they improve employee satisfaction, health, and safety. In addition, training and teamwork have positive impacts on EP, since they provide the capabilities and commitment needed to address environmental problems. Their second investigation discusses the integration of sustainability (environmental and social) into the competitive priorities of different operations strategy configuration models (price oriented, market oriented, and innovation oriented). Their findings suggest that environmental and social priorities are less highly-regarded by price-oriented models, since they compete focused on cost and quality, while market oriented models give more importance to those priorities. Innovation-oriented models show more commitment to social and environmental sustainability, as they compete by differentiation.

Another interesting framework for LM and sustainability integration is proposed by Martínez León and Calvo-Amodio (2017). They acknowledge that this integration is neither trivial nor straightforward, however suggest six propositions to help overcome those difficulties. Their propositions are derived from conclusions of past works (some reviewed in this paper). Propositions one and two focus on the mix and alignment required between lean and sustainability practices. Propositions three and four relate closely to the environmental perspective calling for the introduction of responsible resource management in lean practices, and a systemic approach between lean (especially supply related) and environmental practices. Finally, proposition five emphasizes the importance of the human component in lean and sustainability, while proposition six focus on the need to approach LM implementation in a systematic and structured way.

Regarding SSTP assessment proposed in the literature, unlike traditional operational and economic metrics (OEE, cost, quality, delivery, service, ROI, EBITDA, etc.), Reich-Weiser et al. (2008) agree that there is still a lack of properly applicable and comparable sustainability metrics, and that "*continued research is required on the characterization of sustainability metrics for manufacturing processes to achieve truly sustainable manufacturing technologies*", a gap that is yet to be filled according to Ben Ruben et al. (2017). An interesting approach to deal with this complexity is presented by Helleno et al. (2017), in the form of a series of sustainability KPIs (key performance indicators) derived from the VSM methodology. Their conceptual method was tested in three case studies with pleasant results, however, it does not allow for comparison between different manufacturing processes or companies.

Table 5 presents a summary of metrics, indexes and dimensions proposed in the reviewed literature. It is important to note the way in which they account for EP and SP in separate ways, and that no widespread methodology was found that integrated all three TBL pillars of performance into a holistic measure of SSTP.

3.2.5. *Lean manufacturing and sustainable performance*

Some papers asserting relationships between LM and sustainability do not account for all TBL pillars, and instead consider sustainability to be a form of accounting for environmental impacts along with OP. Verrier et al.'s (2016) paper refers to the TBL perspective when dealing with sustainability. However, in practice, it only addresses OP and EP issues, as is the case in other investigations, which link LM and sustainability in their titles (Ishak et al., 2017; Miller et al., 2010; Nujoom et al., 2017; Vinodh et al., 2011). Martínez León and Calvo-Amodio (2017) framework addresses economic, environmental and social perspectives, but the papers used as references are restricted by the inclusion of the words "environmental" or "green" in all their search strings. Finally, the sustainability component of the OEEE (Overall Environmental

Table 5
Operational, environmental and social performance metrics.

Authors	Operational performance	Environmental performance	Social performance
Gimenez et al. (2012)	Production and operational costs	Energy use, resource use, operations footprint, waste reduction, pollution reduction, emissions reduction, hazardous/harmful/toxic materials use, environmental accidents.	Equitable opportunities, diversity encouraging, community connection, quality of life, democratic processes, accountable governance structures
Gualandris et al. (2014)	Not considered	Biodiversity, air and water pollution, 80. energy, recycling	Working conditions: health and safety, training, human rights: child labor, discrimination
Helleno et al. (2017)	Operation cost, effective cost, stock cost	Power consumption, water consumption, harmful gases release, waste segregation, waste with traceable treatment, green production rate, environmental management system	Absenteeism, turnover, accident rate, noise level, national production, benefits and commissions
Longoni et al. (2014) Longoni and Cagliano (2015)	Cost, delivery, flexibility, quality	Pollution, resource consumption, emissions generation, ecosystem degradation	External (community): social reputation, life quality Internal (workforce): employee satisfaction, creation of skills, health
Piercy and Rich (2015)	Cost, service, quality, waste reduction, productivity	Pollution, emissions, materials used, energy use, emissions from transportation, use of recycled materials, recycling	Workforce: safe working environment, good working conditions, fair wages and payment, non-discrimination, union relations Community: charitable donations, community support
Reich-Weiser et al. (2008)	Cost, quality, return on investment (ROI)	Use of resources: coal, oil, water, energy Environmental impact: pollution, toxicity, climate change	Poverty, gender equality, nutrition, child mortality, sanitation, health, education, housing, crime, employment
Resta et al. (2016)	Generated economic value, distributed economic value, retained economic value	Resource use, Emission to air, Emission to water, Emission to land	Employment, labor/management relations, health & safety, training, diversity and equal opportunity, remuneration, grievance mechanisms.
Silva et al. (2013)	Cost, manufacturing time, material consumption	Energy consumption	Work environment, employee satisfaction
Sajan et al. (2017)	Operational cost, market value, profit	Environmental business wastage, emission/unit production, material usage/output, energy/fuel usage	Safety and health, labor relationship, training and education, consumer complaints
Slaper and Hall (2011)	Income (sales), job growth, revenue	Sales, dollars per KWh, greenhouse gas emissions, use of recycled material, water consumption, waste to landfill, land use.	Training hours per employee, welfare, career retention, charitable contributions, safety incidents rate, job growth.
Vinodh et al. (2016)	Value-added time, value-added cost, raw material consumption, power consumption	Carbon footprint, water eutrophication, air acidification, water consumption	Physical load, work environment risks, noise level

Equipment Effectiveness) proposed by Domingo and Aguado (2015) only represents the environmental component, as it is calculated in terms of achieved gains on environmental impact reduction.

Due to the complexity of the variables and interactions involved in SSTP assessment, and the subjectivity of most non-economic measures (Pagell and Shevchenko, 2014), most papers reviewed in this section consist of case studies (Bergenwall et al., 2012; Helleno et al., 2017; Piercy and Rich, 2015; Resta et al., 2016, 2017; Silva et al., 2013; Vinodh et al., 2016) or frameworks (Abualfaraa et al., 2017; Pagell and Shevchenko, 2014; Sonntag, 2000). Only Thomas et al. (2016) and Sajan et al. (2017) used an empirical research approach, based on surveys, to test different LM-SSTP relationships. Thomas et al. (2016) identified the business profiles of manufacturing companies that lead to increased resiliency and sustainability. Their results provide four different business scenarios, in accordance with sales and cost patterns, the former being affected by turbulent markets, and the latter influenced by manufacturing strategy, including LM implementation.

The first business profile proposed by Thomas et al. (2016), is marked by decreasing sales and increasing operational costs. In the second profile, sales grow over time, but costs grow at a higher rate, making both profiles 1 and 2 unsustainable in the long-term. The third profile has companies with decreasing operational costs (as a result of LM and other similar initiatives), but also with decreasing sales, due to aging product lines. The third profile, by itself, is also unsustainable over time. It gives the company an opportunity to implement "fitness" practices, based on innovation and new markets, in order to increase sales (Pham and Thomas, 2011), and therefore, achieve long-term sustainability.

Companies belonging to the fourth business profile (represented in Fig. 5), are sustainable and resilient organizations (Thomas et al., 2016), and show extensive and embedded use of LM, but only in addition to other strategies, such as supply chain integration, technology integration, agility, and reconfigurability in their operations, as well as sophisticated, innovative and diverse product lines, and a multi-client portfolio for their sales (Pham and Thomas, 2011). In fact, an interesting quote from Thomas et al. (2016) states that "*production managers often cited the issue that the application of Lean, Six Sigma and other process improvement programs were often run as separate change management programs and as such, the programs did not integrate effectively with the production management work being undertaken in the company*". This was found to be the case, particularly with companies in business profiles 1 and 2 (the less sustainable ones), as they employed LM as

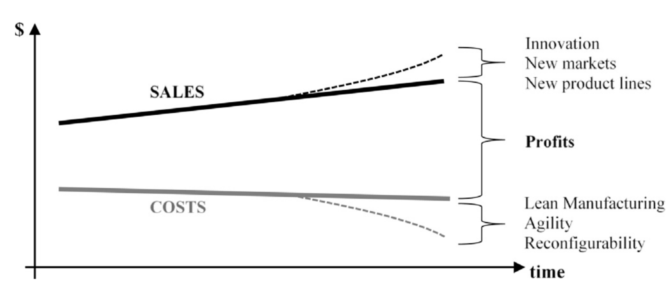

Fig. 5. Business scenario for sustainability (adapted from: Eldenburg and Wolcott, 2011; Pham and Thomas, 2011; Thomas et al., 2016).

a one-time strategy, which was insufficient to provide a significant improvement in SSTP.

The LM – SSTP, and in fact all sustainable manufacturing research, is marked by two trends: the complementary perspective and the trade-offs perspective (Resta et al., 2016). The first supports that there are positive interactions between all three pillars of TBL, as some authors (Galeazzo et al., 2014; Miller et al., 2010; Monge et al., 2013) point to a positive relationship between EP and OP, and others extend it also to SP (Lankoski, 2009; Ocampo and Estanislao-Clark, 2014). From this perspective, performance in all three dimensions is cumulative. Thus, if LM has been proven to deliver positive outcomes in OP, those should further lead to gains in EP, and finally SP.

The second perspective realizes that organizations necessarily face trade-offs between the three pillars of TBL, or at least two of them, most commonly between economic and non-economic performance (Figge and Hahn, 2012; Martínez León and Calvo-Amodio, 2017; Ocampo and Estanislao-Clark, 2014; Pagell and Shevchenko, 2014). This implies that improving in one dimension of performance will necessarily come at the expense of one or both of the others. The findings of Sajan et al. (2017), support the trade-offs perspective, between economic and social dimensions, claiming that a conflict of interests has always been present on companies among those entities of sustainability. Pagell and Shevchenko (2014) suggest that the trade-offs perspective is often found because the management research approach of "does it pay to be sustainable?", implies that environmental and social outcomes must be reduced to profits (or losses). Therefore, companies should focus on both social and environmental practices which do not harm long-term economic performance.

Regarding the LM effect on SSTP, Pagell and Shevchenko (2014) pose the example of a lean automotive supply chain, that, even if it manages to reduce the environmental impact to the minimum in manufacturing, will still deliver a product that leaves a negative environmental footprint, in terms of resource consumption and emissions. A complementary explanation for the observed trade-offs might be that the resources required to continue driving OP, EP, and SP tend to compete against each other (Thomas et al., 2016), and their allocation leads to different levels of performance for each pillar.

Although other authors do not specifically mention the trade-offs perspective, their findings suggest that, at different levels of LM implementation, performance can be affected in one or more of the three pillars. Sonntag (2000) was the first to raise the concern that, as advanced manufacturing technologies (which include LM) can improve operational performance by means of shorter lead-times and faster time to market, they could lead to increased resource consumption in the long-term, in order to sustain the shorter product lifecycle dynamic. Adverse findings were also noted by Silva et al. (2013), who claim that LM is an effective driver for productivity, and that becomes the most relevant factor for the workers involved, while "*the main effects of LM on environmental and social sustainability turned out to be directly related to the reduction of cost*".

The results of Bergenwall et al. (2012), probably the most comprehensive LM – SSTP investigation from a TBL perspective to date, also show mixed outcomes, with concern rising in regards to benefits being achievable only in the short-term. Although their work is limited, as it represents only the case of two North American automotive companies, notable findings include the harmful environmental effects derived from the mismatch between pull and push systems in different links of the value chain. These caused overproduction and excessive inventories, and therefore, increased resource consumption, land use, and emissions. There is also the concern of increased pollution due to the fact that JIT practices require more frequent transport, supported by the claim that "*the adoption of TPS (Toyota Production System) by many Japanese firms in the* 1980s *actually worsened the air quality in Tokyo*". Finally, Bergenwall et al. (2012) also pointed to negative SP outcomes, since American unions are found to be traditionally reluctant to cross-train (one common practice of HRM) in order to protect job security. Hence, workers often feel threatened by the implementation of such LM practices.

Piercy and Rich (2015) and Vinodh et al. (2016) seem fonder of the complementary perspective, although both of them are mostly focused on environmental outcomes. Value Stream Mapping (VSM), regarded as a starting point for LM implementation, can be extended to "map" environmental impacts throughout product lifecycles, improving EP (Vinodh et al., 2016). Worker training, empowerment, standardized work, and visual management tend to deliver higher levels of worker safety (Piercy and Rich, 2015), while supplier development (associated with both JIT and TQM) can improve EP, as synchronization with suppliers leads to less overproduction and transportation.

Similar to lean and green practices, Piercy and Rich's (2015) framework differentiates lean practices from sustainability practices, although they propose a model for integration of the two. Their model starts with operational level (workplace) sustainability, which accounts for waste reduction and improved work conditions, supply chain sustainability, which includes local sourcing and supplier audits, and community sustainability addresses engagement with schools, neighbors and charity sponsorship. Both lean and sustainability practices can be complementary, but need to be implemented using different approaches. As LM starts at the operational level, it can rely either on bottom-up or mid-level-up implementation. Sustainability, however, must be adopted from the organizational strategy, making it more suitable for the top-down approach. It's important to consider that in Piercy and Rich's (2015) investigation (based on case studies), goals, outcomes, or metrics used to assess sustainability effects, especially regarding SP, were different in each company. The authors acknowledge that "*while the change cases here are focused on the positive achievements of each company it should be noted that transformation was not necessarily always smooth*" (Piercy and Rich, 2015).

Most recently, Resta et al. (2017) performed a multi case study on manufacturing companies from different sectors, exploring how the introduction of LM practices contribute to sustainability goals. Their findings support the breadth of positive LM-OP relationship, but further claim that the adoption of HRM practices help to build a "lean culture" in the organization, therefore, positively impacting SP. On the other side, some of the cases presented a negative LM-EP relationship. This seem to be particularly the case in companies where there wasn't a clearly defined sustainability (or environmental) strategy.

Resta et al.'s (2017) results, partially diverge with those of Sajan et al. (2017), since the latter found significant positive effects of LM on all three TBL dimensions. Sajan et al.'s (2017) structural equation model was developed from data of 252 Indian small and medium enterprises. Interestingly, the LM-EP relationship resulted stronger and most significant than LM-OP and LM-SP, but the authors did not provide possible explanations for this result. Therefore, while being an important contribution to the lean and sustainability literature, especially regarding SP, Sajan et al.'s (2017) results are limited by sampling being done in a particular state in India, with multisector companies.

The complexity and multi-dimensional nature of the LM-sustainability interaction has been established in previous sections, with the identified effects of LM on the TBL pillars ranging from positive to negative in the reviewed studies. While this makes the research field open to further studies in the coming years, Table 6 contributes to gather current knowledge of LM effects on TBL, which serves as a starting point for researchers.

An important caveat of LM effects, shown in Table 6, is that some performance dimensions have been found to be affected either positively or negatively. Also, certain authors have found both positive and negative outcomes. An explanation may be provided by number of context variables that can affect LM effectiveness (described in Section 3.2.1), the negative interaction between some lean practices and specific performance dimensions, and also to a failure to view LM as a cohesive philosophy, instead of a set of separately implemented tools (Longoni et al., 2013).

4. Further paths for research

Further research paths identified in the LM – SSTP literature review are presented in Table 7 in the form of research questions consequent from knowledge gaps yet unaddressed on the subject. The first three questions are derived from results presented and discussed in Section 3.2.5, and they should either provide a better understanding of how LM allows for continuous, simultaneous improvement in all three TBL pillars, or force companies to choose to allocate their resources for profitable initiatives at the expense of social and environmental initiatives, following a trade-offs approach.

To answer the first two questions, we propose a "sand-cone" model approach (Bortolotti et al., 2015; Ferdows and De Meyer, 1990; Schroeder et al., 2011), that has OP at the base, and is driven by LM implementation, as seen in Fig. 6. As LM has been proved on several occasions to lead to improved OP (Section 3.2.1), it should provide further resources and further capabilities for investment in and development of the environmental practices which drive EP. Finally, organizational "health", derived from financial stability and decreased environmental impact, should materialize in worker and community well-being. Nevertheless, the proposed sand-cone model for LM ability to build sustainable performance capabilities still needs to be empirically proven.

Question four comes both from the scarcity of research on the social outcomes of LM, and manufacturing strategies in general (Section 3.2.3), and a continuous call from the scientific and academic community to address social challenges derived from manufacturing operations (Cherrafi et al., 2016; Geng et al., 2017; Hartini and Ciptomulyono, 2015; Sutherland et al., 2016). Despite growing interest in environmental and green initiatives related to manufacturing (Garza-Reyes, 2015), a comprehensive understanding of industrial sustainability issues, and more importantly, of how humanity should prepare to embrace them, remains heavily constrained by social-oriented research being in arrears.

Questions five and six arise from FMF and other similar frameworks, proposed in Section 3.2.4, which still require more empirical validation in different contexts, are usually limited by dealing with sustainability from a primarily financial point of view, and do not consider responsible resource management (Martínez León and Calvo-Amodio, 2017). The seventh question arises from the gap existing between Womack et al. (1990) and Liker (2004), thorough studies of TPS and other eastern pioneer LM practitioners, and scarce literature regarding the way that leading LM practitioners are addressing sustainability challenges. This gap could be partially explained by the exclusion of Japanese papers from this review. However, it is still a valid concern for western companies. The final question comes from the inconsistency between different performance measures presented in, and the inability to find an integrating SSTP index or measurement method in the reviewed literature, and the scarcity of standards of benchmarks to compare current social and environmental indicators (Helleno et al., 2017).

Table 6
LM effects on operational, environmental, and social performance.

	Positive effects (improve in)	Negative effects (detriment in)
Operational performance	Cycle time ([1], [2], [7], [10], [24], [30])	Financial performance (in high technological turbulence environments [3], [8], [15], [21], [31])
	Scraps and reworks ([1], [2], [18], [20])	Long-term improvement ([8], [21], [26])
	First pass yield ([1], [2])	Misallocation of resources ([4], [7])
	Manufacturing cost ([1], [2], [5], [6], [7]; [9], [10], [22], [24], [31])	Administrative cost ([4])
	Lead time ([1], [2], [5], [6], [8], [18], [24])	Manufacturing cost (incorrect VSM [7])
	Product quality ([5], [6], [7], [9], [10], [18], [22], [25])	Product quality (incorrect VSM [7])
	Quantity flexibility ([2], [5], [6], [9], [22])	Flexibility (incorrect VSM [7])
	Product mix flexibility ([2], [5], [7])	Lead Time ([18])
	Inventory reduction ([18], [21], [29])	Quality ([9], [10], [18])
Environmental performance	Resource consumption ([11], [14], [16], [20], [24], [25], [27], [28], [29], [30], [31])	
	Pollution control ([11], [14], [20], [24], [25], [27], [28])	Waste disposal ([11], [28])
	Energy efficiency ([12], [13], [14], [16], [20], [24], [25], [28], [29], [30])	Pollution ([11], [21], [27], [28])
	Recycling ([13], [16])	Energy consumption ([21], [28])
	Environmental awareness ([16], [17], [25], [28])	Trade-offs with operational performance ([23])
	Carbon footprint ([17])	VOC emissions ([28])
Social performance		Employee reluctance to cross-training ([21])
	Multifunctional teams ([4], [29], [30])	Employee mistrust ([4], [26], [29])
	Health and safety ([9], [14], [25], [28], [29], [30])	Safety ([9], [21])
	Continuous improvement ([9])	Work climate ([9], [19], [28])
	Employee satisfaction ([17], [18], [25], [28], [29], [30])	Routine operation ([10], [21], [29])
		Traffic ([11], [21], [28], [29])
		Trade-offs with operational performance ([23])

[1]: Shah and Ward (2003); [2]: Dal Pont et al. (2009); [3]: Chavez et al. (2015); [4]: Čiarnienė and Vienažindienė (2014); [5]: Bortolotti et al. (2015); [6]: Zhao et al. (2014); [7]: Belekoukias et al. (2014); [8]: Pham and Thomas (2011); [9]: Longoni et al. (2013); [10]: Ketokivi and Schroeder (2004); [11]: Bandehnezhad et al. (2012); [12]: Torielli et al. (2011); [13]: Miller et al. (2010); [14]: Verrier et al. (2016); [15]: Galeazzo et al. (2014); [16]: Jabbour et al. (2013); [17]: Monge et al. (2013); [18]: Negrão et al. (2017); [19]: Nordin and Belal (2017); [20]: Vinodh et al. (2011); [21]: Bergenwall et al. (2012); [22]: Domingo and Aguado (2015); [23]: Besiou and Van Wassenhove (2015); [24]: Vinodh et al. (2016); [25]: Piercy and Rich (2015); [26]: Thomas et al. (2016); [27]: Pagell and Shevchenko (2014); [28]: Resta et al. (2017); [29]: Resta et al. (2016); [30]: Silva et al. (2013); [31]: Sonntag (2000).

Table 7
Research questions for further research.

#	Research questions
1.	Does LM help to build cumulative capacities for management of economic, environmental, and social performance?
2.	Are environmental and social practices addressed in an "as long as they pay off" way by companies?
3.	Do higher levels of LM implementation force trade-offs between resources focused on operational, environmental, and social outcomes?
4.	Which social issues and challenges arise from the implementation of LM practices, and how they should be addressed?
5.	Can "fit manufacturing" be considered a proper evolution of LM for management of sustainability concerns, and which practices should be considered/added as fit practices?
6.	Can LM be configured to perform in low resource availability environments as a long-term performance enhancing philosophy?
7.	What are LM pioneer companies as Toyota doing to address sustainability? Are those practices already known and implemented by western companies?
8.	Is it possible to design a holistic sustainable performance metric, using the TBL perspective, that provides comparable results between different companies?

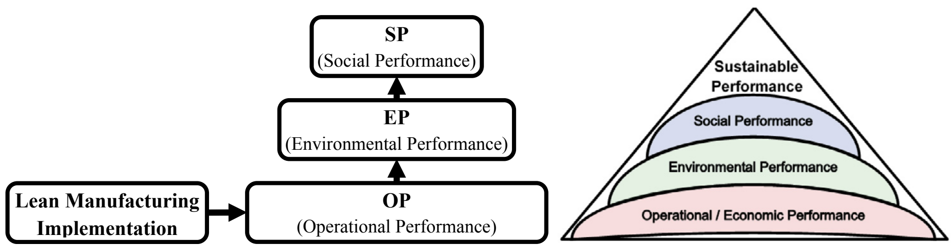

Fig. 6. Sustainable performance sand-cone model.

5. Conclusions

This paper contributes to the LM and sustainability literature by being the first systematic literature review linking LM to sustainable performance, using the TBL approach, which accounts for economic/operational, environmental, and social performance outcomes. It shows the extent to which the current state of research has addressed the effects of LM in sustainable performance, and provides paths to further extend academic and scientific knowledge on the matter.

As a result of the information provided by the reviewed literature, it may be concluded that two major trends characterize LM vs. sustainable performance research. The first trend points to LM acting as a positive catalyst for all three TBL pillars at the same time, thus achieving the virtuous cycle of cumulative performance gains for each dimension of performance (i.e. operational, environmental, and social). Some articles present evidence of LM positively affecting all three TBL pillars at the same time, while evidence also suggests that strong operational performance can support environmental and social programs, which, in turn, provide financial returns for the continued support of LM initiatives. This we call the "cumulative trend", which implies that some degree of balance must exist between all three TBL pillars. Performance gains resulting from LM implementation become cumulative in all of these.

The second main trend, which we call "trade-offs trend", proposes that, at higher levels of performance, LM implementation requires a significant commitment of resources, which can draw attention away from social and environmental initiatives. One group of evidence suggests that LM can have both positive and negative effects on each TBL pillar, which may be explained, from this perspective, by the need for companies to make trade-offs between two (or even all three) pillars, in order to continue making performance gains in a given dimension. This condition can also be supported by evidence from companies which adopt social and environmental initiatives "as long as they pay off", but which eliminate them when financial or operational performance deteriorates. This makes LM a "burden" to employees, and, without the proper support for environmental-friendly practices, operational gains may come at the expense of social and environmental performance.

Evidence hints that both of the aforementioned trends have been observed in companies, which may be contradictory. This leaves unanswered questions regarding those factors that lead to the emergence of one scenario or the other. The reviewed literature suggests that a positive interaction between LM and OP can be achieved, in most cases, as long as human, context, and sequence factors are considered. In order to achieve significant EP improvements, it is most likely that LM practices need to be complemented by specifically developed green or environmental practices, which nevertheless, could be helped to succeed by previous LM implementation.

Regarding SP, there is the need for further research, aimed at understanding the way that LM affects organizational SP. Also, it is necessary to define and adopt more widely-accepted indexes and dimensions to measure social performance, both from internal and external perspectives. This problem arises mainly due to the relative novelty and scarcity of literature in operations management that addresses social issues. In addition, commonly accepted and widespread measurement scales for sustainability need to be developed, according to the current and future needs of the stakeholders involved, so as to better understand how companies are performing, and therefore develop more effective paths to improve sustainable performance, since the LM – sustainability integration remains one of the major challenges in current operations management research.

Concerning the most commonly employed research methods, the complexity of the variables and phenomena involved in current LM vs performance research requires more complex research approaches, such as action research, longitudinal data analysis, multicase studies, or ethnographic studies, among other methods, suited to showing better paths to sustainability, without leaving aside empirical and survey methods suited to finding general relationships between practices and performance. The efficient integration of the aforementioned research approaches with LM practitioners and companies poses an important challenge to the academic community, as managers are often wary, for good reason, of researchers attempting to experiment with the manufacturing, supply, and delivery processes.

The systematic literature review presented in the preceding sections allowed for the identification of important trends, regarding the ways in which LM affects each of the three TBL pillars of performance (Section 3.2), and also point to certain issues that are still unsettled in the literature. These are transformed into the questions in Table 7. To conclude, investigations linking LM and SSTP are still scarce, and results range from positive to negative interactions and outcomes. This makes the field of study a promising ground for future research, as it is important to gain adequate clarity in the short and mid-term of whether LM is enough as a paradigm to achieve proper levels of sustainability in the manufacturing industry, or if it must be complemented by other practices and philosophies.

It is important to mention that some limitations exist regarding the approach, reach, and conclusions of this study. Firstly, as mentioned throughout this document, LM principles and practices trace their roots to TPS and other manufacturing paradigms, which originated in Japan. This study does not include literature written in Japanese, which may have led to the exclusion of relevant papers, especially relating to industry leading companies, as expressed in the sixth question in Table 7. Secondly, as this paper follows a TBL approach to sustainability, as stated in Section 2, further research could also consider investigations linking LM and sustainability under other sustainability approaches and paradigms. Finally, the scarcity of papers relating LM to social outcomes, and especially work containing empirical evidence, makes it difficult to arrive to more definitive conclusions regarding the effects of LM in social performance.

Finally, it can be concluded that current LM research still falls short of properly identifying, proving, and more importantly addressing issues regarding its impact on long-term sustainability, while pressure from stakeholders increases every day for the development of sufficiently effective, applicable, and scalable manufacturing strategies and practices, which positively reinforce all three TBL pillars, and discard or replace those which do not.

References

Abualfaraa, W.A., Salonitis, K., Al-Ashaab, A., 2017. Improving sustainability of manufacturing systems through integrated sustainable value stream mapping tool – conceptual framework. In: Gao, J., El Souri, M., Keates, S. (Eds.), 15th Int. Conf. Manuf. Res. Inc. 32nd Natl. Conf. Manuf. Res. IOS Press, Greenwich, pp. 371–376. https://doi.org/10.3233/978-1-61499-792-4-371.

Alhuraish, I., Robledo, C., Kobi, A., 2017. A comparative exploration of lean manufacturing and six sigma in terms of their critical success factors. J. Clean. Prod. 164, 325–337. https://doi.org/10.1016/j.jclepro.2017.06.146.

Ahmad, A., Mehra, S., Pletcher, M., 2004. The perceived impact of JIT implementation on firms' financial/growth performance. J. Manuf. Technol. Manag. https://doi.org/10.1108/09576060410513715.

Arroyo, P., Gonzalez, V., 2016. Rethinking waste definition to account for environmental and. In: Proc. 24rd Annu. Conf. Int. Gr. Lean Constr, pp. 13–22. Boston.

Arcidiacono, G., Costantino, N., Yang, K., 2016. The AMSE lean six sigma governance model. Int. J. Lean Six Sigma 7, 233–266. https://doi.org/10.1108/IJLSS-06-2015-0026.

Avella, L., Vázquez-Bustelo, D., 2010. The multidimensional nature of production competence and additional evidence of its impact on business performance. Int. J. Oper. Prod. Manag. 30, 548–583. https://doi.org/https://doi.org/10.1108/01443571011046021.

Azevedo, S.G., Carvalho, H., Duarte, S., Cruz-Machado, V., 2012. Influence of green and lean upstream supply chain management practices on business sustainability. IEEE Trans. Eng. Manag. 59, 753–765. https://doi.org/10.1109/TEM.2012.2189108.

Bandehnezhad, M., Zailani, S., Fernando, Y., 2012. An empirical study on the contribution of lean practices to environmental performance of the manufacturing firms in northern region of Malaysia. Int. J. Value Chain Manag. 6, 144. https://doi.org/10.1504/IJVCM.2012.048379.

Belekoukias, I., Garza-Reyes, J.A., Kumar, V., 2014. The impact of lean methods and tools on the operational performance of manufacturing organisations. Int. J. Prod. Res. 52, 5346–5366. https://doi.org/10.1080/00207543.2014.903348.

Ben Ruben, R., Vinodh, S., Asokan, P., 2018. Lean Six Sigma with environmental focus: review and framework. Int. J. Adv. Manuf. Technol. 94, 4023–4037. https://doi.org/10.1007/s00170-017-1148-6.

Ben Ruben, R., Asokan, P., Vinodh, S., 2017. Performance evaluation of lean sustainable systems using adaptive neuro fuzzy inference system: a case study. Int. J. Sustain. Eng. 10, 158–175.

Bergenwall, A.L., Chen, C., White, R.E., 2012. TPSs process design in American automotive plants and its effects on the triple bottom line and sustainability. Int. J. Prod. Econ. 140, 374–384. https://doi.org/10.1016/j.ijpe.2012.04.016.

Bergmiller, G.G., Mccright, P.R., 2009. Parallel models for lean and green operations. Ind. Eng. Res. Conf. 1138–1143.

Besiou, M., Van Wassenhove, L.N., 2015. Addressing the challenge of modeling for decision-making in socially responsible operations. Prod. Oper. Manag. 24, 1390–1401. https://doi.org/10.1111/poms.12375.

Bhamu, J., Sangwan, K.S., Singh Sangwan, K., 2014. Lean manufacturing: literature review and research issues. Int. J. Oper. Prod. Manag. 34, 876–940. https://doi.org/10.1108/IJOPM-08-2012-0315.

Bortolotti, T., Danese, P., Flynn, B.B., Romano, P., 2015. Leveraging fitness and lean bundles to build the cumulative performance sand cone model. Int. J. Prod. Econ. 162, 227–241. https://doi.org/10.1016/j.ijpe.2014.09.014.

Bortolotti, T., Danese, P., Romano, P., 2012. Assessing the impact of just-in-time on operational performance at varying degrees of repetitiveness. Int. J. Prod. Res. https://doi.org/10.1080/00207543.2012.678403.

Busse, C., 2016. Doing well by doing good? The self-interest of buying firms and sustainable supply chain management. J. Supply Chain Manag. 52, 28–47. https://doi.org/10.1111/jscm.12096.

Büyüközkan, G., Kayakutlu, G., Karakadılar, İ.S., 2015. Assessment of lean manufacturing effect on business performance using Bayesian belief networks. Expert Syst. Appl. 42, 6539–6551. https://doi.org/10.1016/j.eswa.2015.04.016.

Ceulemans, K., Molderez, I., Van Liedekerke, L., 2015. Sustainability reporting in higher education: a comprehensive review of the recent literature and paths for further research. J. Clean. Prod. 106, 127–143. https://doi.org/10.1016/j.jclepro.2014.09.052.

Chavez, R., Yu, W., Jacobs, M., Fynes, B., Wiengarten, F., Lecuna, A., 2015. Internal lean practices and performance: the role of technological turbulence. Int. J. Prod. Econ. 160, 157–171. https://doi.org/10.1016/j.ijpe.2014.10.005.

Cherrafi, A., Elfezazi, S., Chiarini, A., Mokhlis, A., Benhida, K., 2016. The integration of lean manufacturing, Six Sigma and sustainability: a literature review and future research directions for developing a specific model. J. Clean. Prod. 139, 828–846. https://doi.org/10.1016/j.jclepro.2016.08.101.

Chiarini, A., 2014. Sustainable manufacturing-greening processes using specific Lean Production tools: an empirical observation from European motorcycle component manufacturers. J. Clean. Prod. 85, 226–233. https://doi.org/10.1016/j.jclepro.2014.07.080.

Čiarnienė, R., Vienažindienė, M., 2014. How to facilitate implementation of lean concept? Mediterr. J. Soc. Sci. 5, 177–183. https://doi.org/10.5901/mjss.2014.v5n13p177.

Corbett, C.J., Klassen, R.D., 2006. Extending the horizons: environmental excellence as key to improving operations. Manuf. Serv. Oper. Manag. 8, 5–22. https://doi.org/10.1287/msom.1060.0095.

Dal Pont, G., Furlan, A., Vinelli, A., 2009. Interrelationships among lean bundles and their effects on operational performance. Oper. Manag. Res. 1, 150–158. https://doi.org/10.1007/s12063-008-0010-2.

Danese, P., Manfè, V., Romano, P., 2018. A systematic literature review on recent lean research: state-of-the-art and future directions. Int. J. Manag. Rev. 20, 579–605. https://doi.org/10.1111/ijmr.12156.

Despeisse, M., Vladimirova, D., 2014. Decision making for sustainability: review and research agenda. In: Grabot, B., Vallespir, B., Gomes, S., Bouras, A., Kiritsis, D. (Eds.), IFIP Adv. Inf. Commun. Technol. Springer, Berlin, pp. 146–153. https://doi.org/10.1007/978-3-662-44736-9_18.

Distelhorst, G., Hainmueller, J., Locke, R.M., 2017. Does lean improve labor standards? Management and social performance in the Nike supply chain. Manag. Sci. 63, 707–728. https://doi.org/10.1287/mnsc.2015.2369.

Domingo, R., Aguado, S., 2015. Overall environmental equipment effectiveness as a metric of a lean and green manufacturing system. Sustainability 7, 9031–9047. https://doi.org/10.3390/su7079031.

Eldenburg, L., Wolcott, S., 2011. Cost Management: Measuring, Monitoring, and Motivating Performance, second ed. Wiley, USA.

Elkington, J., 2004. Enter the triple bottom line. In: Henriques, A., Richardson, J. (Eds.), The Triple Bottom Line: Does it All Add up? Earthscan, London, pp. 1–16.

Elkington, J., 1998. Partnerships from Cannibals with Forks: the triple bottom line of 21st-century business. Environ. Qual. Manag. 8, 37–51. https://doi.org/10.1002/tqem.3310080106.

Elkington, J., 1994. Towards the sustainable corporation: win-win-win business strategies for sustainable development. Calif. Manag. Rev. 36, 90–100. https://doi.org/10.2307/41165746.

Espejo Alarcón, M., Moyano Fuentes, J., 2007. Lean Production : Estado actual Y Desafíos Futuros de La Investigación. Investig. Eur. Dir. y Econ. la Empres. 13, 179–202.

Ferdows, K., De Meyer, A., 1990. Lasting improvements in manufacturing performance: in search of a new theory. J. Oper. Manag. 9, 168–184. https://doi.org/10.1016/0272-696390)90094-T.

Figge, F., Hahn, T., 2012. Is green and profitable sustainable? Assessing the trade-off between economic and environmental aspects. Int. J. Prod. Econ. 140, 92–102. https://doi.org/10.1016/j.ijpe.2012.02.001.

Florida, R., 1996. Lean and green: the move to environmentally conscious manufacturing. Calif. Manag. Rev. 39, 80–105. https://doi.org/10.2307/41165877.

Friedman, M., 1970. The social responsibility of business is to increase its profits. N. Y. Times Mag. 122–126.
Galeazzo, A., Furlan, A., Vinelli, A., 2014. Lean and green in action: interdependencies and performance of pollution prevention projects. J. Clean. Prod. 85, 191–200. https://doi.org/10.1016/j.jclepro.2013.10.015.
Ghalehkhondabi, I., 2017. Developing customer order penetration point within production lines. In: Newsvendor Supply Chains, and Supply Chains with Demand Uncertainties in Two Consecutive Echelons. Ohio University.
Garza-Reyes, J.A., 2015. Lean and green – a systematic review of the state of the art literature. J. Clean. Prod. 102, 18–29. https://doi.org/10.1016/j.jclepro.2015.04.064.
Geng, R., Mansouri, S.A., Aktas, E., 2017. The relationship between green supply chain management and performance: a meta-analysis of empirical evidences in Asian emerging economies. Int. J. Prod. Econ. 183, 245–258. https://doi.org/10.1016/j.ijpe.2016.10.008.
Gimenez, C., Sierra, V., Rodon, J., 2012. Sustainable operations: their impact on the triple bottom line. Int. J. Prod. Econ. 140, 149–159. https://doi.org/10.1016/j.ijpe.2012.01.035.
Gobinath, S., Elangovan, D., Dharmalingam, S., 2015. Lean manufacturing issues and challenges in manufacturing process – a review. Int. J. ChemTech Res. 8, 44–51.
Gualandris, J., Golini, R., Kalchschmidt, M., 2014. Do supply management and global sourcing matter for firm sustainability performance? Supply Chain Manag. Int. J. 19, 258–274. https://doi.org/10.1108/SCM-11-2013-0430.
Gupta, S., Sharma, M., Sunder, M.,V., 2016. Lean services: a systematic review. Int. J. Prod. Perform. Manag. 65, 1025–1056. https://doi.org/10.1108/IJPPM-02-2015-0032.
Gupta, S.M., 2016. Lean manufacturing, green manufacturing and sustainability. J. Jpn. Ind. Manag. Assoc. 67, 102–105.
Hallam, C., Contreras, C., 2016. Integrating lean and green management. Manag. Decis. 54, 2157–2187. https://doi.org/10.1108/MD-04-2016-0259.
Hartini, S., Ciptomulyono, U., 2015. The relationship between lean and sustainable manufacturing on performance: literature review. Procedia Manuf. 4, 38–45. https://doi.org/10.1016/j.promfg.2015.11.012.
Helleno, A.L., de Moraes, A.J.I., Simon, A.T., 2017. Integrating sustainability indicators and Lean Manufacturing to assess manufacturing processes: application case studies in Brazilian industry. J. Clean. Prod. 153, 405–416. https://doi.org/10.1016/j.jclepro.2016.12.072.
Ishak, A., Mohamad, E., Sukarma, L., Mahmood, A.R., Rahman, M.A., Yahya, S.H., Salleh, M.S., Sulaiman, M.A., 2017. Cleaner production implementation using extended value stream mapping for enhancing the sustainability of lean manufacturing. J. Adv. Manuf. Technol. 11, 47–60.
Jabbour, C.J.C., Jabbour, A.B.L. de S., Govindan, K., Teixeira, A.A., Freitas, W.R. de S., 2013. Environmental management and operational performance in automotive companies in Brazil: the role of human resource management and lean manufacturing. J. Clean. Prod. 47, 129–140. https://doi.org/10.1016/j.jclepro.2012.07.010.
Jasti, N.V.K., Kodali, R., 2014. Lean production: literature review and trends. Int. J. Prod. Res. 53, 1–19. https://doi.org/10.1080/00207543.2014.937508.
Ketokivi, M., Schroeder, R., 2004. Manufacturing practices, strategic fit and performance: a routine-based view. Int. J. Oper. Prod. Manag. 24, 171–191. https://doi.org/10.1108/01443570410514876.
Kowang, T.O., Yong, T.S., Rasli, A., Long, C.S., 2016. Lean six sigma sustainability framework: a case study on an automotive company. Asian J. Sci. Res. 9, 279–283. https://doi.org/10.3923/ajsr.2016.279.283.
Lankoski, L., 2009. Cost and revenue impacts of corporate responsibility: comparisons across sustainability dimensions and product chain stages. Scand. J. Manag. 25, 57–67. https://doi.org/10.1016/j.scaman.2008.10.002.
Liker, J.K., 2004. The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer. McGraw-Hill, New York.
Longoni, A., Cagliano, R., 2015. Environmental and social sustainability priorities: their integration in operations strategies. Int. J. Oper. Prod. Manag. 35, 216–245. https://doi.org/10.1108/IJOPM-04-2013-0182.
Longoni, A., Golini, R., Cagliano, R., 2014. The role of New Forms of Work Organization in developing sustainability strategies in operations. Int. J. Prod. Econ. 147, 147–160. https://doi.org/10.1016/j.ijpe.2013.09.009.
Longoni, A., Pagell, M., Johnston, D., Veltri, A., 2013. When does lean hurt? – an exploration of lean practices and worker health and safety outcomes. Int. J. Prod. Res. 51, 3300–3320. https://doi.org/10.1080/00207543.2013.765072.
Machuca, J.A.D., Ortega Jimenez, C.H., Garrido-Vega, P., Perez de Los Rios, J.L., 2011. Do technology and manufacturing strategy links enhance operational performance? Empirical research in the auto supplier sector. Int. J. Prod. Econ. 133, 541–550. https://doi.org/10.1016/j.ijpe.2010.12.010.
Maginnis, M.A., Hapuwatte, B.M., Jawahir, I.S., 2017. Implementing total lifecycle product sustainability through true lean thinking. In: Ríos, J., Bernard, A., Bouras, A., F.S (Eds.), Prod. Lifecycle Manag. Ind. Futur. PLM 2017. IFIP Adv. Inf. Commun. Technol. Springer, pp. 544–553. https://doi.org/10.1007/978-3-319-72905-3_48.
Martínez León, H.C., Calvo-Amodio, J., 2017. Towards lean for sustainability: understanding the interrelationships between lean and sustainability from a systems thinking perspective. J. Clean. Prod. 142, 4384–4402. https://doi.org/10.1016/j.jclepro.2016.11.132.
Martínez-Jurado, P.J., Moyano-Fuentes, J., 2014. Lean management, supply chain management and sustainability: a literature review. J. Clean. Prod. 85, 134–150. https://doi.org/10.1016/j.jclepro.2013.09.042.
Miller, G., Pawloski, J., Standridge, C.R., 2010. A case study of lean, sustainable manufacturing. J. Ind. Eng. Manag. 3, 11–32. https://doi.org/10.3926/jiem.2010.v3n1.p11-32.
Mollenkopf, D., Stolze, H., Tate, W.L., Ueltschy, M., 2010. Green, lean, and global supply chains. Int. J. Phys. Distrib. Logist. Manag. 40, 14–41. https://doi.org/10.1108/09600031011018028.
Monge, C., Cruz, J., López, F., 2013. Impacto de la manufactura esbelta, manufactura sustentable y mejora continua en la eficiencia operacional y responsabilidad ambiental en México. Inf. Tecnol. 24, 15–32. https://doi.org/10.4067/S0718-07642013000400003.
Negrão, L.L.L., Godinho Filho, M., Marodin, G., 2017. Lean practices and their effect on performance: a literature review. Prod. Plann. Contr. 28, 33–56.
New, S.J., 2007. Celebrating the enigma: the continuing puzzle of the Toyota production system. Int. J. Prod. Res. 45, 3545–3554. https://doi.org/10.1080/00207540701223386.
Nordin, N., Belal, H.M., 2017. Change agent system in lean manufacturing implementation for business sustainability. Int. J. Supply Chain Manag. 6, 271–278.
Nujoom, R., Mohammed, A., Wang, Q., 2017. A sustainable manufacturing system design: a fuzzy multi-objective optimization model. Environ. Sci. Pollut. Res. 1–13. https://doi.org/10.1007/s11356-017-9787-6.
Ocampo, L.A., Estanislao-Clark, E., 2014. Developing a framework for sustainable manufacturing strategies selection. DLSU Bus. Econ. Rev. 23, 115–131.
Pagell, M., Shevchenko, A., 2014. Why research in sustainable supply chain management should have No future. J. Supply Chain Manag. 50, 44–55.
Pagell, M., Wu, Z.H., 2009. Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars. J. Supply Chain Manag. 45, 37–56. https://doi.org/10.1111/j.1745-493X.2009.03162.x.
Papadopoulou, T.C., Özbayrak, M., 2005. Leanness: experiences from the journey to date. J. Manuf. Technol. Manag. 16, 784–807. https://doi.org/10.1108/17410380510626196.
Pham, D.T., Thomas, A., 2005. Fighting fit factories: making industry lean, agile and sustainable. Manuf. Eng. 84, 24–29. https://doi.org/10.1049/me:20050204.
Pham, D.T., Thomas, A.J., 2011. Fit manufacturing: a framework for sustainability. J. Manuf. Technol. Manag. 23, 103–123. https://doi.org/10.1108/17410381211196311.
Pham, D.T., Williams, O.A., Thomas, A., 2011. A framework for fit manufacturing. Int. J. Comput. Aided Eng. Technol. 3, 415. https://doi.org/10.1504/IJCAET.2011.040056.
Piercy, N., Rich, N., 2015. The relationship between lean operations and sustainable operations. Int. J. Oper. Prod. Manag. 35, 282–315. https://doi.org/10.1108/IJOPM-03-2014-0143.
Prasad, S., Khanduja, D., Sharma, S.K., 2016. An empirical study on applicability of lean and green practices in the foundry industry. J. Manuf. Technol. Manag. 27, 408–426. https://doi.org/10.1108/JMTM-08-2015-0058.
Rahman, S., Laosirihongthong, T., Sohal, A.S., 2010. Impact of lean strategy on operational performance: a study of Thai manufacturing companies. J. Manuf. Technol. Manag. 21, 839–852. https://doi.org/10.1108/17410381011077946.
Reich-Weiser, C., Vijayaraghavan, A., Dornfeld, D.A., 2008. Metrics for sustainable manufacturing. In: ASME 2008 Int. Manuf. Sci. Eng. Conf. Vol. ASME, Evanston, USA, pp. 327–335. https://doi.org/10.1115/MSEC_ICMP2008-72223.
Resta, B., Dotti, S., Gaiardelli, P., Boffelli, A., 2017. How lean manufacturing affects the creation of sustainable value: an integrated model. Int. J. Autom. Technol. 11, 542–551. https://doi.org/10.20965/ijat.2017.p0542.
Resta, B., Dotti, S., Gaiardelli, P., Boffelli, A., 2016. Lean manufacturing and sustainability: an integrated view. In: Nääs, I., et al. (Eds.), Adv. Prod. Manag. Syst. Initiat. a Sustain. World. APMS 2016. Springer, Iguassu, pp. 659–666. https://doi.org/10.1007/978-3-319-51133-7_78.
Robledo, S., Osorio, G.A., López, C., 2014. Networking en pequeña empresa: una revisión bibliográfica utilizando la teoria de grafos. Rev. Vínculos 11, 6–16.
Rothenberg, S., Pil, F.K., Maxwell, J., 2001. Lean, green, and the quest for superior environmental performance. Prod. Oper. Manag. 10, 228–243. https://doi.org/10.1111/j.1937-5956.2001.tb00372.x.
Sajan, M.P., Shalij, P.R., Ramesh, A., Biju Augustine, P., 2017. Lean manufacturing practices in Indian manufacturing SMEs and their effect on sustainability performance. J. Manuf. Technol. Manag. 28, 772–793. https://doi.org/10.1108/JMTM-12-2016-0188.
Schroeder, R., Shah, R., Xiaosong, D., 2011. The cumulative capability "sand cone" model revisited: a new perspective for manufacturing strategy. Int. J. Prod. Res. 49, 4879–4901. https://doi.org/10.1080/00207543.2010.509116.
Seuring, S., Seuring, S., Muller, M., Muller, M., 2008. From a literature review to a conceptual framework for sustainable supply chain management. J. Clean. Prod. 16, 1699–1710. https://doi.org/10.1016/j.jclepro.2008.04.020.
Shah, R., Ward, P., 2003. Lean manufacturing: context, practice bundles, and performance. J. Oper. Manag. 21, 129–149. https://doi.org/10.1016/S0272-696302)00108-0.
Silva, C., Vaz, P., Ferreira, L.M., 2013. The impact of Lean Manufacturing on environmental and social sustainability: a study using a concept mapping approach. IFAC Proc. 46, 306–310.
Singh, B., Sharma, S.K., 2009. Value stream mapping as a versatile tool for lean implementation: an Indian case study of a manufacturing firm. Meas. Bus. Excell. 13, 58–68. https://doi.org/10.1108/13683040910984338.
Singh, K., Ahuja, I.P.S., 2012. Transfusion of total quality management and total productive maintenance: a literature review. Int. J. Technol. Pol. Manag. 12, 275. https://doi.org/10.1504/IJTPM.2012.050135.
Slaper, T., Hall, T., 2011. The triple bottom Line : what is it and how does it work? Indiana Bus. Rev. 4–8.

Sonntag, V., 2000. Sustainability — in light of competitiveness. Ecol. Econ. 34, 101–113. https://doi.org/10.1016/S0921-800900)00141-5.
Stone, K.B., 2012. Four decades of lean: a systematic literature review. Int. J. Lean Six Sigma 3, 112–132. https://doi.org/10.1108/20401461211243702.
Sutherland, J.W., Richter, J.S., Hutchins, M.J., Dornfeld, D., Dzombak, R., Mangold, J., Robinson, S., Hauschild, M.Z., Bonou, A., Schönsleben, P., Friemann, F., 2016. The role of manufacturing in affecting the social dimension of sustainability. CIRP Ann. 65, 689–712. https://doi.org/10.1016/j.cirp.2016.05.003.
Taggart, P., Kienhöfer, F., 2013. The effectiveness of lean manufacturing audits in measuring operational performance improvements. S. Afr. J. Ind. Eng. 24, 140–154.
Thanki, S., Govindan, K., Thakkar, J., 2016. An investigation on lean-green implementation practices in Indian SMEs using analytical hierarchy process AHP) approach. J. Clean. Prod. 135, 284–298. https://doi.org/10.1016/j.jclepro.2016.06.105.
Thomas, A., Byard, P., Francis, M., Fisher, R., White, G.R.T., 2016. Profiling the resiliency and sustainability of UK manufacturing companies. J. Manuf. Technol. Manag. 27, 82–99. https://doi.org/10.1108/JMTM-06-2014-0086.
Torielli, R.M., Abrahams, R.A., Smillie, R.W., Voigt, R.C., 2011. Using lean methodologies for economically and environmentally sustainable foundries. China Foundry 8, 74–88.
Verrier, B., Rose, B., Caillaud, E., 2016. Lean and green strategy: the lean and green house and maturity deployment model. J. Clean. Prod. 116, 150–156. https://doi.org/10.1016/j.jclepro.2015.12.022.
Vinodh, S., Arvind, K.R., Somanaathan, M., 2011. Tools and techniques for enabling sustainability through lean initiatives. Clean Technol. Environ. Policy 13, 469–479. https://doi.org/10.1007/s10098-010-0329-x.
Vinodh, S., Ben Ruben, R., Asokan, P., 2016. Life cycle assessment integrated value stream mapping framework to ensure sustainable manufacturing: a case study. Clean Technol. Environ. Policy 18, 279–295.
WBCSD, 2011. A Vision for Sustainable Consumption. World Business Council for Sustainable Development, Geneva.
WCED, 1987. Report of the World Commission on Environment and Development: Our Common Future. https://doi.org/10.1080/07488008808408783. Oxford paperbacks.
Womack, J.P., Jones, D.T., Roos, D., 1990. The Machine that Changed the World: the Story of Lean Production. Free Press, New York.
Yang, C.-L.L., Lin, S.-P.P., Chan, Y.H., Sheu, C., 2010. Mediated effect of environmental management on manufacturing competitiveness: an empirical study. Int. J. Prod. Econ. 123, 210–220. https://doi.org/10.1016/j.ijpe.2009.08.017.
Yusup, M.Z., Mahmood, W.H.W., Salleh, M.R., 2015. Basic formation in streamlining lean practices in manufacturing operations - a review. Int. J. Adv. Oper. Manag. 7, 255. https://doi.org/10.1504/IJAOM.2015.075024.
Zhao, W., Yu, Q., Li, H., Tian, Y., 2014. Study on the relationship between JIT practices and operational performance based on the cost leading strategy. In: 2014 Int. Conf. Manag. Sci. Eng. 21th Annu. Conf. Proc. IEEE, pp. 329–334. https://doi.org/10.1109/ICMSE.2014.6930248.
Zhu, Q., Sarkis, J., 2004. Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises. J. Oper. Manag. 22, 265–289. https://doi.org/10.1016/j.jom.2004.01.005.