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# DOES LEAN PRACTICES IMPLEMENTATION IMPACT ON COMPANY PERFORMANCE? A META-ANALYTICAL RESEARCH

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Abstract

Studies linking the use of lean practices to company performance have been increasing as markets are becoming more competitive and companies are eager for reducing waste and therefore implementing the Lean Management (LM) philosophy to improve performance. However, results from these studies have found various and different impacts and some light is needed. Extant literature was reviewed and, to achieve the research objective, a meta-analysis of correlations was carried out. The obtained results suggest a positive relationship between some lean practices and performance measures. Furthermore, the presence of moderators influencing the relationship between lean practices and performance outcomes is highlighted in our results. To our best knowledge, this is the first research that proposes a comparison of results from primary studies on Lean implementation, by analysing the linear relationship between lean practices and enterprise performance. It fills this gap and therefore represents an important contribution.

Keywords

Lean manufacturing, performance evaluation, meta-analysis, manufacturing systems, company.

## Introduction

In this age of globalization, markets are increasingly competitive, and the customization of products is common. This poses a huge challenge to manufacturing companies: pressure to reduce costs and rapidly adapt to ever-changing customer tastes [1]. Based on several previous ideologies (Just-in-Time (JIT), Zero Inventories, and Toyota Production System (TPS)), Lean Management (LM) emerged as an answer to these new market requirements [2], and it has been attracted several attention, not only from scientific researchers but also from managers and consultants worldwide [3]. By focusing on waste elimination [4], Lean philosophy allows the production of goods and services at the lowest cost, and as fast as customers require them, with no additional resources.

The adoption of Lean has not been equally successful across firms, and depends on the type of industry, region, or country [5]. Moreover, contextual factors, such as production system and product characteristics, may as well affect the success of the lean practices implementation [6]. Therefore, several studies have been directed to understand and analyse the impact of LM on firms' performance (e.g.: [5, 7]).

The main aim of this research is to analyse the effect of LM implementation on companies' performance by using meta-analysis. Specifically, whether LM implementation positively impacts companies' performance. If so, whether all lean practices affect all company performance measures and which ones produce a greater impact. Lastly, the influence of moderating factors (contextual factors, e.g., plant size or age, geographic region [8]) on the relationship between lean practices and company performance is also studied. To accomplish it, a meta-analysis of correlations is used, enabling the researcher to either evaluate previous studies as a whole and overcome difficulties (e.g. sampling error, measurement error and restriction range [9]).

Concerning primary studies, the proposed analysis on the LM implementation is known to be the first research that compares and combines results of previous reports and analyses the linear correlation of lean practices and enterprise performance. Recently, Liu et al. [10] reported a combined meta-analytic approach with Bayesian networks. However, our work differs very considerably by several important reasons: we focus on the linear side of the relationship (not non-linear side); our set of primary articles is much larger (77 versus 21 articles) and the time-span is much wider (1990–2017 vs 2009–2017); we correct correlations for the most damaging errors while the other work does not perform any correction and we investigate the presence of moderating factors, which is not done in [10]. Finally, we analyse practice by practice, individually, while the other study does not go into this depth of analysis.

Besides filling a gap in the literature and, therefore, representing an important contribution for the investigation on this topic, this study provides a broader insight for managers that enables the interpretation of empirical conclusions from the primary studies that will be very useful while implementing LM in their firms.

This paper is organized as follows. In the next section, a literature review concerning aspects related with LM implementation and company performance measures is performed. Then, the methodological consideration is fully presented and, afterwards, the main results are discussed and the findings are debated. Finally, in last section, conclusion, directions for future research and limitations of the study are presented.

## Literature review

The concept of LM drives from the Toyota Production System [1, 11]. To fulfil the customers demand, the Japanese engineers Eiji Toyoda and Taiichi Ohno developed the TPS in the 1950s, which was targeted to eliminate all types of waste and inconsistency within the production system [3, 12, 13].

The generic term "lean" first emerged via John Krafcik [15], a researcher from the Massachusetts Institute of Technology (MIT), which focused on bridging the notable performance gap between Western and Japanese automotive industries at the time [14]. Yet, the "lean production" term is cited as being popularized in manufacturing by the authors Womack et al. [4] through their book The Machine That Changed the World, which emerged from the study at MIT [13, 15].

No definition of lean is consensual in the extant literature [16]. Overtime, several authors have differently classified lean as either a philosophy, a way, a concept, among others [1]. Nevertheless, Womack et al. [4] do not offer a specific definition, even though they describe a lean system in detail. Ghosh [12] states that the scholar community sees lean production mainly at three levels: i) philosophical level: to eliminate waste [4, 12] and improve customer value [12, 17]; ii) the intermediate level that represents the five lean principles related to production; and iii) operational level where lean is viewed as a group of tools and techniques [12, 18, 19].

According to Shah and Ward [8], lean practices can be combined into four bundles: Just-in-Time (JIT), Total Quality Management (TQM), Total Preventive Maintenance (TPM) and Human Resource Management (HRM). Each bundle represents a group of inter-related lean practices. The extant literature identifies several practices associated to lean implementation. Pettersen [16] identified Setup time reduction, Continuous improvement, and Pull production as central to the lean concept. *Poka-yoke* and *Heijunka* are also perceived as central. Shah and Ward [8] have also listed the most frequent lean practices: Continuous improvement, Cross-functional workforce, JIT, Lot size reductions, Pull system, Quick changeover techniques, Self-directed work teams, and TQM. Sezen et al. [20] also summarized the lean techniques empirically examined in the literature.

The implementation of lean practices is often related with operational performance improvements [8]. Both quantitative and qualitative benefits associated to lean implementation have been reported by numerous authors (e.g., [1, 2, 21, 22]). Although several organizations have reported high benefits of lean implementation, others were not able to accomplish the desired results [1]. In fact, there is not a stepwise guideline or process to lean implementation, which faces many challenges or barriers [1, 23, 24]. Jadhav et al. [23] identified 24 challenges to an effective implementation of LM. Among them, the lack of resources to invest, lack of top management involvement and workers' attitude or resistance are the most cited barriers in the reviewed literature. Moreover, the success of lean implementation is not completely based on the practices' application, but relies on the relationship between workers and top management.

Several empirical research has analysed the impact of lean practices on performance. While some authors have found positive associations between practices and performance (e.g., [8, 25]), others found that not all practices yield positive outcomes (e.g., [7, 26, 27]).

Researchers have also investigated the role of contextual factors on the relationship between lean implementation and performance. Shah and Ward [8] analysed the influence of plant size, unionization and plant age, finding a strong support for the influence of plant size. Mackelprang and Nair [28] also suggest some moderating factors for the lean-performance is relationship. Cua et al. [25] found that manufacturing performance is better explained by plant internal practices and techniques than it is by the context in which the plant operates.

Considering the extant literature review, a meta-analysis of correlations allows the integration of results across studies and, consequently, the clarification of the impact of lean practices on the company performance. We analyse the following hypotheses:

Hypothesis 1 – LM implementation is positively correlated with company performance.

Hypothesis 2 – Lean practice $i$ is positively correlated with performance measure $j$.

$i$ = Quick changeover techniques, Pull system, One piece flow, Equipment layout, *Heijunka, Jidoka*, Inventory reduction, Small lot size, Supplier involvement, *Kaizen*, Cross-functional teams, Self-directed work teams and Preventive maintenance;

$j$ = Operational, Financial and Market performance and Aggregate performance.

Hypothesis 3 – The relationship between lean practices and performance measures is affected by moderators, contextual factors.

## Materials and methods

Meta-analysis, known as "analysis of the analysis" ([29], p. 3), has been widely recognized as a fundamental tool for integrating knowledge, and largely utilized by academic literature for further theory development [9].

Among several methods that can be applied, Field and Gillet [30] suggest the use of Hunter and Schmidt [31]. This research follows the same methodological approach proposed by [31], which has also been widely used by other researchers (e.g., [28, 42, 43]).

The aim of meta-analysis of correlations is to provide a description of the distribution of actual correlations between independent and dependent variables of a given phenomenon [31]. Empirical studies are vulnerable to imperfections that cause errors in the results and, consequently, make the study correlation to diverge from the real correlation. Some of the imperfections can be corrected. For example, in the case of sampling error, the use of additional information such as study sample sizes, among others, leads to more reliable conclusions [31]. Following [31] and in line with [28], this study considers both non-significant and significant correlations between lean practices and performance measures, with the aim of reducing potential bias in the outcomes.

### Construct operationalization

The following 13 practices were selected based on an extensive literature review, and thus it is believed that they represent a fairly view of the main components of LM implementation: Quick changeover techniques [32, 33], Pull system [11, 33], One piece flow [20], Equipment layout [33–35], *Heijunka* [11, 36, 37], *Jidoka* [11, 26], Inventory reduction [20, 38], Small lot size [28, 39]; Supplier involvement [33], *Kaizen* [20, 26]; Flexible cross-functional teams [8, 40], Self-directed work teams [20, 33]; and Preventive maintenance [33, 41].

Regarding the performance, several measures are used in empirical studies on LM implementation. In this research, company performance is conceptualized in three multi-item types of performance: the operational performance (e.g., quality, manufacturing cost, etc.), the financial performance (e.g., profitability, return on assets, etc.) and the market performance (e.g., market share, customer satisfaction, etc.).

Concerning moderators, since the basis for the meta-analytic procedures employed in this research is prescribed in [31], the presence or not of contextual factors is assessed by a ratio (RATIO2), whose calculation is detailed below. Depending on its value, moderators are likely present or not.

### Sample

To obtain the data for this study, a literature search of relevant articles was conducted on databases such as SCOPUS, EBSCO, B-On and Google Scholar. To ensure a complete coverage of articles linking lean practices to company performance, specific keywords were searched on those databases: 'Lean'; 'Just-in-Time'; 'TQM'; 'HRM, Lean' and 'TPM' each of them combined with the keyword 'Performance'. The search was limited to pertinent subject areas as: Business Management; Economics and Finance; and Social Sciences. Moreover, two specific articles were included as sources: [44], a literature review of articles that study lean practices and their effect on performance, and [28].

Five criteria were subsequently developed for screening studies concerning inclusion in this research. First, the data must be collected from primary sources through a survey; Therefore, case studies and other qualitative studies were excluded. Second, it is included articles published between 1990 and 2017, since the concept of lean became popular in the nineties. The third criterion requires that the study must analyse the direct relationship between lean practices and performance, using statistical techniques. Fourth, the articles must provide data from at least one relation between one dependent and one independent variables; Consequently, articles studying the impact of lean as a single construct (e.g., degree of leanness, TQM, etc.) were excluded from analysis. The fifth criterion requires that articles must provide the minimum quantitative data that are needed to perform the meta-analysis.

After applying the five criteria listed above, our sample was reduced to 77 articles, which compares favorably to other meta-analysis (e.g., [10, 28, 42, 43, 45]. The 77 articles are: [8, 26, 52–126].

## Research methodology

The basis for the meta-analytic procedures employed in this research is described in [31]. Following the approach of [31] as other studies do (e.g. [28, 46, 47]), we calculate the following: the Attenuation factor ($A$); the Corrected study correlations ($r'$); the Individual study weights ($W_i$); the Corrected study sampling error variance ($e_i$); the Weighted mean sampling error variance ($\overline{e}$); the Weighted mean corrected correlations ($\overline{r}'$); the Variance of the corrected correlations ($\sigma^2_{r'}$); the estimate of the Population standard deviation ($S_p$); RATIO1; RATIO2; and the Credibility interval (CI). The Credibility interval corresponds to the interval that contains the percentage selected of the values in the correlation distribution. In addition to correlations, for each study it was needed to collect information regarding sample size and reliabilities to correct the correlations for sampling and measurement errors. Missing reliabilities were replaced by average reliabilities [31].

The meta-analysis was performed in two stages. At the first stage, it was examined the relationship between lean practices and performance at an aggregate level. Aggregate lean was defined as a cumulative set including all lean practices, and Aggregate performance as a cumulative set including all performance measures. Specifically, the variables were computed as in [48]: the correlation between Aggregate lean and Aggregate performance was calculated by averaging the correlations between lean practices and performance measures included in each study. Also, the average of reliability estimates of lean practices in each study was used as the Aggregate lean reliability. Similarly, the average of the reliability estimates of the performance measures was used as the performance reliability in each study (in order to limit the length of the paper the full database is available upon request from the authors).

At the second stage, it was analysed the relationship between specific lean practices and performance measures. Due to insufficient data available regarding the variables One piece flow and Inventory reduction, these were entirely excluded from further analysis. All the detailed data used in this section of the analysis is available upon request.

To interpret the results [31] proposed two heuristics: RATIO1 and RATIO2 (see Table 1 for its formula). RATIO1 serves to infer whether the population correlation significantly diverges from zero. This ratio is based on the concept of credibility interval, a concept similar to confidence interval, with the use of the standard deviation of correlations rather than the standard error. When RATIO1 is higher or equal to 2, it is likely that the population correlation is larger than zero; therefore, if the population correlation is normally distributed, the probability of a correlation being lower or equal to zero is less than 5%. Departures from normality do not change much the analysis, shown by [49]. The lower endpoint of the credibility interval only modestly changes with the distribution shape. RATIO2 is used to analyse

Table 1
Formulas used in the meta-analysis calculations.

| |
|---|
| $(\alpha_{xx})^{1/2} \times (\alpha_{yy})^{1/2}$, where $(\alpha_{xx})$ and $(\alpha_{yy})$ are the Reliability of lean practices and the Reliability of performance measures, respectively. |
| $r' = r/A$, where $r$ is the Study correlations. |
| $W_i = N \times A^2$, where $N$ is the Study sample size. |
| $e_i = (1 - \overline{r}^2)^2/(N-1)A^2$, where $\overline{r}$ is the Weighted sample mean correlations. |
| $\overline{e} = \sum W_i e_i / \sum W_i \qquad \overline{r}' = \sum W_i r' / \sum W_i \qquad \sigma^2_{r'} = \sum W_i [r' - \overline{r}']^2 / \sum W_i.$ |
| $S_p = [(\sigma^2_{r'}) - (\overline{e})]^{1/2} \qquad \mathrm{RATIO1} = \overline{r}'/S_P \qquad \mathrm{RATIO2} = \overline{e}/\sigma^2_{r'}.$ |
| $\mathrm{CI} = \overline{r}' \pm Z \times S_p$, where $Z$ is the $Z$-value of desired credibility level. |

the existence of moderation effects. It represents the amount of the observed variance that is due to the existence of artifacts. A RATIO2 higher or equal to 0.75 indicates that there is only one population correlation, and consequently the relationship is not subject to moderators; if RATIO2 is lower than 0.75, then moderators are likely present [50].

## Results and discussion

### Aggregated and individual analysis

The first hypothesis to be tested is the theoretically assumed positive link between LM implementation and company performance. Considering the heuristics previously presented, the relationship between Aggregate lean and Aggregate performance was not found to be significantly positively correlated, with a value of RATIO1 equal to 1.680. Therefore, the null hypothesis cannot be rejected. The credibility interval for the population correlation between lean and performance is [−0.056; 0.733], which means that, if the normality assumptions are satisfied, 95% of the values of the distribution of population correlation are within this range. The width of the interval represents the variety of the effect sizes' magnitude of population correlation distribution and, since it includes 0, it cannot be asserted a valid positive correlation between lean practices and performance. Regarding the presence of moderating factors, the value of RATIO2 is 0.118. Since it is lower than 0.75, it can be concluded that the relationship between Aggregate lean and Aggregate performance is influenced by moderators.

The second goal of this research is to identify whether individual lean practices are positively correlated with performance outcomes, both at individual and aggregate levels. The results are presented in Table 2, where lean practices are classified according to the four bundles proposed by Shah and Ward [8]: JIT, TQM, HRM and TPM. Values of RATIO1 higher than 2 and RATIO2 lower than 0.75 are indicated in bold.

Regarding Quick changeover techniques, this practice proved to be positively correlated with Aggregate performance and Financial performance, since RATIO1 values are higher than 2. However, even though it is positively correlated with Aggregate performance, this practice was not found to be positively correlated with Operational performance. Due to lack of data, it was not possible to analyse the relationship between Quick changeover techniques and Market performance. The practice Pull system was found to be positively correlated with all performance measures at individual levels. However, when considered at an aggregate level, it was not found a positive correlation. With regard to the e Equipment layout, we were unable to examine its relationship with Market performance, owing to inexistence of studies. This practice was only found to be positively correlated with Financial performance. Considering *Heijunka*, the practice proved to have a positive correlation with Operational performance. Due to lack of data available, we were not able to study the relationship between *Heijunka* and Financial and Market performances. Furthermore, the relationship between *Heijunka* and Aggregate performance has little meaning, since it is mostly related to articles studying Operational performance, and only one is related to Financial performance.

At individual level, Kaizen was only found to be positively correlated with Financial Performance. However, when considering financial, operational and market measures all together, the practice proves to be positively correlated with them. The practices Small lot size, Supplier involvement, Flexible, cross-functional teams and Preventive maintenance were not found to be positively correlated with any of the performance measures.

From a performance perspective, the results indicate that Operational performance is positively correlated with Pull system, *Heijunka* and *Jidoka*; Financial performance is positively correlated with Quick changeover techniques, Pull system, Equipment layout, *Kaizen* and Self-directed work teams; and Market performance is positively correlated with Pull system, *Jidoka* and Self-directed work teams.

The third hypothesis to be tested is whether moderators influence the relationship between lean practices and performance measures. From Table 2, it is clear that the overall relationship between lean practices and performance measures is influenced by moderators. Only the relationships Pull system vs Market performance, Equipment layout/Self-directed work teams vs Financial performance and *Jidoka* vs Aggregate performance revealed to not be influenced by moderators. Thus, the Hypothesis 3 is supported.

This result indicates that the context under which the practices are implemented has impact on the outcomes produced by them.

Our results are summarized in Table 3. To better understanding of the results, two columns were added to the table representing two calculations: the percentage of possible significant outcomes, and the average of the significant corrected correlations. The percentage may assign the extensiveness or breadth of the impact, and it is considered high when one individual lean practice improves multiple performance measures (regardless the cases where there is not enough data for analysis). The average of the significant corrected correlations shall represent deepness of the impact; it captures the magnitude of the significant corrected correlations between practices and performance outcomes.

Table 2
Meta-Analysis of correlations results: Lean practices classified by bundles.

| | | | # of studies | Weighted Sample Mean Correlations ($r'$) | Weighted Mean Corrected Correlations ($\overline{r}'$) | Mean Error Variance ($\overline{e}$) | Variance of Corrected Correlat. ($\sigma^2 r'$) | Estimate population SD ($S_p$) | RATIO1 | RATIO2 |
|---|---|---|---|---|---|---|---|---|---|---|
| JIT | Quick changeover techniques | OP | 20 | 0.158 | 0.199 | 0.006 | 0.019 | 0.114 | 1.751 | **0.314** |
| | | FP | 6 | 0.184 | 0.229 | 0.011 | 0.019 | 0.093 | **2.47** | **0.552** |
| | | MP | 1 | Insufficient data for analysis | | | | | | |
| | | AP | 23 | 0.193 | 0.239 | 0.006 | 0.017 | 0.104 | **2.293** | **0.353** |
| | Pull system | OP | 22 | 0.186 | 0.232 | 0.006 | 0.01 | 0.064 | **3.624** | **0.598** |
| | | FP | 4 | 0.284 | 0.332 | 0.008 | 0.018 | 0.102 | **3.269** | **0.428** |
| | | MP | 2 | 0.338 | 0.375 | 0.008 | 0.004 | 0 | ∞ | 1.848 |
| | | AP | 25 | 0.221 | 0.27 | 0.006 | 0.034 | 0.168 | 1.608 | **0.176** |
| | Equipment layout | OP | 15 | 0.172 | 0.219 | 0.005 | 0.022 | 0.127 | 1.725 | **0.253** |
| | | FP | 3 | 0,247 | 0,32 | 0,014 | 0,016 | 0,04 | **8,045** | 0,899 |
| | | MP | 0 | Insufficient data for analysis | | | | | | |
| | | AP | 17 | 0.168 | 0.214 | 0.006 | 0.022 | 0.125 | 1.714 | **0.279** |
| | *Heijunka* | OP | 12 | 0.158 | 0.202 | 0.012 | 0.022 | 0.099 | **2.03** | **0.55** |
| | | FP | 1 | Insufficient data for analysis | | | | | | |
| | | MP | 0 | Insufficient data for analysis | | | | | | |
| | | AP | 12 | 0.163 | 0.208 | 0.012 | 0.022 | 0.101 | **2.072** | **0.542** |
| | Jidoka | OP | 6 | 0.223 | 0.282 | 0.011 | 0.023 | 0.109 | **2.594** | **0.486** |
| | | FP | 1 | Insufficient data for analysis | | | | | | |
| | | MP | 3 | 0.314 | 0.375 | 0.006 | 0.008 | 0.046 | **8.233** | **0.74** |
| | | AP | 7 | 0.352 | 0.427 | 0.008 | 0.004 | 0 | ∞ | 1.771 |
| | Small lot size | OP | 11 | 0.183 | 0.223 | 0.004 | 0.018 | 0.118 | 1.893 | **0.232** |
| | | FP | 3 | 0.161 | 0.185 | 0.005 | 0.062 | 0.239 | 0.772 | **0.076** |
| | | MP | 2 | 0.205 | 0.236 | 0.004 | 0.02 | 0.127 | 1.863 | **0.182** |
| | | AP | 11 | 0.179 | 0.218 | 0.004 | 0.017 | 0.111 | 1.971 | **0.255** |
| TQM | Supplier involvement | OP | 18 | 0.202 | 0.242 | 0.007 | 0.12 | 0.336 | 0.72 | **0.055** |
| | | FP | 7 | 0.168 | 0.214 | 0.011 | 0.045 | 0.187 | 1.145 | **0.233** |
| | | MP | 8 | 0.205 | 0.252 | 0.005 | 0.032 | 0.165 | 1.532 | **0.164** |
| | | AP | 29 | 0.322 | 0.403 | 0.006 | 0.083 | 0.279 | 1.442 | **0.066** |
| | Kaizen | OP | 17 | 0.389 | 0.471 | 0.007 | 0.067 | 0.246 | 1.913 | **0.101** |
| | | FP | 5 | 0.318 | 0.383 | 0.011 | 0.031 | 0.141 | **2.715** | **0.346** |
| | | MP | 5 | 0.273 | 0.308 | 0.006 | 0.033 | 0.167 | 1.844 | **0.166** |
| | | AP | 29 | 0.391 | 0.474 | 0.006 | 0.054 | 0.218 | **2.177** | **0.116** |
| HRM | Flexible, cross-functional teams | OP | 14 | 0.124 | 0.133 | 0.008 | 0.194 | 0.431 | 0.31 | **0.042** |
| | | FP | 3 | 0.288 | 0.394 | 0.017 | 0.058 | 0.203 | 1.94 | **0.29** |
| | | MP | 5 | 0.191 | 0.224 | 0.008 | 0.036 | 0.169 | 1.327 | **0.211** |
| | | AP | 23 | 0.269 | 0.332 | 0.006 | 0.163 | 0.396 | 0.837 | **0.037** |
| | Self-directed work teams | OP | 18 | 0.184 | 0.221 | 0.007 | 0.146 | 0.374 | 0.59 | **0.044** |
| | | FP | 3 | 0.239 | 0.304 | 0.018 | 0.017 | 0 | ∞ | 1.021 |
| | | MP | 5 | 0.279 | 0.333 | 0.004 | 0.028 | 0.154 | **2.171** | **0.156** |
| | | AP | 30 | 0.311 | 0.374 | 0.007 | 0.119 | 0.335 | 1.118 | **0.055** |
| TPM | Preventive maintenance | OP | 13 | 0.298 | 0.379 | 0.009 | 0.066 | 0.239 | 1.585 | **0.132** |
| | | FP | 1 | Insufficient data for analysis | | | | | | |
| | | MP | 0 | Insufficient data for analysis | | | | | | |
| | | AP | 16 | 0.396 | 0.486 | 0.007 | 0.102 | 0.308 | 1.575 | **0.07** |

OP, FP, MP, AP: Operational, Financial, Market and Aggregate Performance, respectively
RATIO1 values in bold indicate a significant correlation; RATIO2 values in bold indicate the absence of moderating influences

Table 3
Impact analysis of individual lean practices on performance measures.

| Bundle | Lean practice | Operational performance | | | Financial performance | | | Market performance | | | Percentage of possible significant outcomes | Average significant corrected correlations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RATIO1 | RATIO2 | | RATIO1 | RATIO2 | | RATIO1 | RATIO2 | | | |
| JIT | Quick Changeover Techniques | 1.7514 | **0.3136** | n.s. | **2.4704** | **0.5518** | **X*** | n/a | n/a | – | Medium (50%) | 0.229 |
| | Pull System | **3.6238** | **0.5982** | **X*** | **3.269** | **0.428** | **X*** | ∞ | 1.8484 | **X** | Very High (100%) | 0.3129 |
| | Equipment Layout | 1.7246 | **0.2531** | n.s. | **8.0446** | 0.8986 | **X** | n/a | n/a | – | Medium (50%) | 0.32 |
| | *Heijunka* | **2.03** | **0.5502** | **X*** | n/a | n/a | – | n/a | n/a | – | Very High (100%) | 0.202 |
| | Jidoka | **2.5943** | **0.4859** | **X*** | n/a | n/a | – | **8.2331** | **0.7401** | **X*** | Very High (100%) | 0.3285 |
| | Small Lot Size | 1.8931 | **0.2318** | n.s. | 0.7719 | **0.0764** | n.s. | 1.8628 | **0.1819** | n.s. | – | – |
| TQM | Supplier Involvement | 0.7196 | **0.0549** | n.s. | 1.1449 | **0.233** | n.s. | 1.5317 | **0.1639** | n.s. | – | – |
| | *Kaizen* | 1.9131 | **0.1012** | n.s. | **2.7149** | **0.3462** | **X*** | 1.8443 | **0.166** | n.s. | Very Low (33%) | 0.383 |
| HRM | Flexible, Cross-func. Teams | 0.3097 | **0.0416** | n.s. | 1.9397 | **0.2896** | n.s. | 1.3266 | **0.2107** | n.s. | – | – |
| | Self-directed Work Teams | 0.5904 | **0.0442** | n.s. | ∞ | 1.0209 | **X** | **2.1706** | **0.156** | **X*** | Medium (67%) | 0.3189 |
| TPM | Preventive Maintenance | 1.5854 | **0.1318** | n.s. | n/a | n/a | – | n/a | n/a | – | – | – |

RATIO1 values in bold indicate a significant correlation; RATIO2 values in bold indicate the absence of moderating influences

X – significant positive correlation; * – subject to moderating factors; n.s. – not significative correlation; n/a – not analysed (insuff data)

From the table, it is possible to conclude that Pull System, *Heijunka* and *Jidoka* yield the greatest effect in terms of extensiveness of impact, influencing positively all the analysed performance measures. It is important to note that *Heijunka* has a very high breadth of impact but only one performance measure was analysed due to lack of data available. Considering the deepness of the impact, the magnitudes of the average significant corrected correlations do not considerably differ among individual practices, ranging from 0.202 to 0.383. Even though *Kaizen* presents very low coverage of impact, it is the practice with the highest depth of impact.

## Discussion

The meta-analysis conducted in this study is motivated by the prominence of LM in Operations Management research field. This study offers an overview of relationship between Lean practices and company performance.

At an individual level analysis, given the results, it should not be expected that all lean practices will yield improvements of all performance measures. Furthermore, the analysis also suggests that some practices yield greater performance benefits than others. In the JIT bundle, Pull system, *Jidoka* and *Heijunka* are the practices that have a positive correlation with Operational, Financial and/or Market performance (with the highest impact). Actually, it is the bundle with the greatest number of practices positively correlating performance. Moreover, these three practices yield the greatest effect in terms of breadth of impact, influencing in a positive way all the analysed performance measures. This may be explained by the essence of Lean: it emerged based on previous ideologies like JIT, Zero inventories, TPS [2]. Among others bundles, only *Kaizen* practice proved to have a positive correlation with Financial performance and Aggregate performance. Kaizen has been evolving to a concept more than a practice: reducing defects and enhancing quality and continuous improvement ('change is good') may have led to an emphasizing of the importance of Kaizen to improve Performance [26, 51]. The results differ from [28] findings, in what concerns the practices that are common (Quick changeover techniques, Small lot sizes, *Heijunka*, Preventive maintenance, Equipment layout and Pull system). Those authors found all practices to be positively correlated with the aggregate performance (equivalent to our operational performance variable, since those authors only analysed operational measures). This discrepancy may be explained by the different number of studies used. According to [31], the higher the number of studies included in the sample, the better the estimate of the actual population correlation. Thus, while [28] confined their meta-analysis to articles published until 2008 in a specific number of journals, resulting in a sample of 25 articles, ours not only includes articles published after 2008 but also uses articles from a broader range of journals.

The analysis of moderating factors evidenced that almost all pairs of relationships are influenced by those factors. The context under which the practices are implemented has impact on the outcomes produced by them. Mackelprang and Nair [28] also found a significant influence of moderating factors in almost half of their examined relationships. Cua et al. [25] and Shah and Ward [8] analysed the effect of process type, plant size, plant age and capacity utilization and found a strong support for the influence of some of these moderators.

Concerning this research and evaluating at an aggregate level, the results did not prove a significant positive relationship between Lean practices implementation and company performance. On one hand, this was a surprising finding, given the widespread adoption of LM and the conceptually assumed benefits derived from its implementation. On the other hand, other studies previously analysed have found some lean practices to have lower or even negative impact on performance measures. [7, 26] and [27] found that not all lean practices yield positive outcomes. Therefore, considering the combination of such results, our finding may not be entirely unexpected. Reinforcing this result, [23]'s research showed that the success of lean implementation is not completely based on the practices application.

## Theoretical implications

The theoretical advance from this research in LM is fourfold. First, there is an improved conceptual understanding of the relationships between LM practices and Company performance.

Second, this study showed the presence of contextual factors which influences almost all pairs of relationships. Considering the influence of unknown moderating factors on lean practices, to examine whether there is an influence of external factors, it is suggested that some moderators should be defined and tested. For example, geographic location, time of the study, type of industry, age of the company, stage of Lean implementation, product mix variety or product innovation. Actually, according to [5], the adoption of lean practices is not equal for all firms and it may vary among companies, depending on the type of industry, region or country. Also, in a study of the effect of contextual factors and the relationship between lean manufacturing and performance (in USA manufacturing companies), [8] found a strong support for the impact of plant size on lean implementation and a less pervasive than expected effect of unionization and plant age.

Third, while some Lean practices influence certain performance measures, there is a need to investigate mediation mechanisms that would strengthen its impact not only on company performance, but also on customers and on environment. [27], used operation responsiveness to mediate the relationship, while studying the relationship between lean practices and company's growth performance.

Fourth, this research sheds several lights on the relationship between lean practices and performance and identifies gaps in the current literature. For example, i) whether the practices should be simultaneously or sequentially implemented, as the practices may interact with one another; ii) scarcity or inexistence of primary studies on certain practices (e.g., One piece flow and Inventory reduction) and pairs of relationships (see Table 3).

## Managerial implications

The findings of this research can act as a guide for managers who consider LM implementation as an option. It was possible to identify the Lean practices that have a positive relationship with performance measures, assessed individually, by the operational, financial and/or market outcomes or through an aggregate measure. Therefore, managers can select for implementation the practices which have the highest positive correlation with Operational, Financial and/or Market performance. In fact, managers act under a (very) limited resources real scenario, thus they have constantly to manage the trade-offs between investment and future return. Knowing where to start enables a tremendous advantage. In our research, we found that the practices Pull system, *Jidoka* and *Heijunka* have the greatest effect in terms of breadth of impact, influencing in a positive way all the analysed performance measures.

Considering the influence of unknown moderating variables for moderators, managers should take into account the underlying context when implementing lean. For instance, even though Quick changeover techniques was found to be positively related to Aggregate performance, it should not be expected this to happen in every context under which that practice is implemented.

## Conclusions, limitations and directions for future research

This research clarifies the relationship between lean practices and company performance measures. Overall, it was found that not all practices influence all performance outcomes. Moreover, the context under which the practices are implemented has an impact on the outcome they produce.

Despite the worldwide adoption of LM, this research suggests that several relationships between lean practices and performance measures have to be subject to further empirical research: One Piece Flow and Inventory Reduction were not object of analysis due to the lack of articles studying them; furthermore, other pairs of relationships such as Quick changeover techniques – Market performance did not have sufficient available data for analysis.

Our research has two main limitations. First, our meta-analysis only corrects two (although the most damaging) out of the eleven "artifacts" identified by [31]: measurement and sampling errors. Second, when reliabilities were not available, it was necessary to replace them by the average reliabilities across all studies, which might not exactly reflect the true properties of the variables.

Given the proved influence of moderating factors, it would be interesting to shed some light on this aspect in future research and analyse which specific factors most influence the relationship between lean practices and performance measures. For instance, it would be important to study the impact of the geographic location on the results.

Finally, future research should also provide insights on how LM should be implemented: whether the practices should be simultaneously or sequentially implemented, as the practices may interact with one another, which may lead to different levels of improved performance.

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