A literature review on lean maturity level tools

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Abstract
This paper aims to present a literature review on Lean tools, Lean maturity level tools in companies and tools for performance analysis. The results are a preliminary study for the development of a new model and process for analysis of Lean maturity level.

Keywords: Lean Assessment, Lean Maturity Level, Lean Tools

INTRODUCTION

Numerous enterprises already passed, are passing or intend to pass through the Lean implementation process. According to Abdulmaleka and Rajgopal (2007), the main goal of the implementation of this process is to maintain the competitiveness of an organization in an increasingly globalized market. As reported by Pay (2008), the number of deployments reaches 70% of the industries in the United States, but only 2% of them have fully achieved its objectives and 74% of them admitted they are not reaching relevant progress with the Lean culture. In the UK, Bhasin (2008) states that the success rate is about less than 10%.

In accordance with Im and Lee (1989), it has been well documented that Lean improves productivity and competitiveness, what are the tools and "what" should be done. However, the implementation is not a simple process, according to the research of these authors it is possible to state that even before the 90's there was already some concern about "how" to implement Lean practices. Thereby, it is clear that the need of finding a way to ensure an effective an also

sustainable implementation of Lean is growing. As stated by Wan and Chen (2009), provide information to support decisions on "how to become Lean" is clearly an important demand.

Therefore, it is possible to notice that there is a great effort in the literature on models checking Lean maturity in companies. In order to verify the research on this subject, Walter and Tubino (2013) built a systematic literature review. As a result, they obtained 46 articles published between 1996 and 2012. In order to update the data generated by these authors, this article will present those studies identified by the authors and, in addition, will present 9 studies that were found between 2012 and 2015. Moreover, a revision about the Lean tools and performance analysis processes will be done.

METHODOLOGY

As input for this research, we used the Walter and Tubino (2013) publication, which is a systematic literature review on Lean maturity level tools, including publications between 1996 and 2012. In the present research, we analyzed all the 48 models presented by these authors, further 8 models from the works' update, totaling 54. From these, 3 were excluded because they treat about application of models already evaluated, so the result of this research is based on analysis of 51 models. The used method follow the steps described in Table 1.

Table 1 – Method

#	**Step**
1	Research conducted at CAPES database
2	Search by title or subject of the following words combined with 'Lean*': Assessment, Measure*, Model*, Metric e Index
3	Search by title or subject of the following words combined with 'Just in Time': Assessment, Measure*, Model*, Metric e Index
4	Selection of papers only
5	In the first study Tubino and Walter (2013) did not restrict the publication year, for the upgrade it was restricted between 2012 and 2015

The criterion to choose the CAPES database, according to Meirelles and Machado (2007), is justified because of its wide coverage and ease access for the Brazilian scientific community to electronic versions of the main scientific journals.

LEAN TOOLS

According to Anvari *et al*. (2014), the choice of tools is one of the crucial factors for the success or failure of the Lean application in organizations. Moreover, the maturity level and the goals only will be achieved, in fact if the tools and techniques have been well chosen and implemented. In order to perform a brief review of these tools, the Table 2 was designed to show the tools discussed in the literature. To support it, highly relevant articles about the topic and more recent literature reviews were used.

Table 2 – Lean tools and techniques

***Lean* Tools and Principles**	**Ohno (1997)**	**Liker (2006)**	**Bhasin e Burcher (2006)**	**Gupta e Kundra (2012)**	**Bhamu e Sangwan (2014)**	**Jasti e Kodali (2014)**	**Total**
Kaizen / Continuous Improvement	X	X	X	X	X	X	**6**
Workload leveling (*Heijunka*)	X	X	X	X	X	X	**6**
Pull Production (*Kanban*)	X		X	X	X	X	**5**
Visual Management	X	X	X		X	X	**5**
Single Minute Exchange of Die (SMED)	X		X	X	X	X	**5**
5S	X		X	X	X	X	**5**
Total Preventive Maintenance (TPM)	X		X	X	X	X	**5**
Just in time	X	X		X	X	X	**5**
Standardized Work	X	X			X	X	**4**
Value Stream Mapping (VSM)	X			X	X	X	**4**
Continuous Production Flow	X	X	X			X	**4**
Supplier Development			X		X	X	**3**
Autonomation (*Jidoka*)	X	X			X		**3**
Cellular Manufacturing			X		X	X	**3**
Poka yoke	X			X	X		**3**
Multifunctional Teams					X	X	**2**
Total Quality Management (TQM)				X	X	X	**3**
Training People		X	X				**2**
Commitment of Employees and Management			X			X	**2**
Challenging Customers and Suppliers		X				X	**2**
Reduction of Supply Base			X			X	**2**
Unit lots / reduction of production batches	X					X	**2**
Empowerment			X				**1**
Hoshin-Kanri	X						**1**
Root Cause Analysis	X						**1**
Zero Defects						X	**1**
Reliable and Tested Technology		X					**1**
Process Mapping			X				**1**
Radical Improvement (*Kaikaku*)			X				**1**
Flexible Information System						X	**1**
Stocks Replacement Point	X						**1**
Simulation					X		**1**
Total	**17**	**10**	**16**	**10**	**17**	**22**	

As a result of the evaluation of the data presented by the Table 2, it is concluded that there are several tools and techniques, and there is no exact rule about their relevance. The result is stated by Im and Lee (1989), who affirm that is necessary build a system adapted to the organization's characteristics and there is no list of the set best characteristics, or which are the 'right' tools. Another finding are the new tools that are emerging, such as the Flexible Information System and the use of computer simulation associated with the Lean.

LEAN MATURITY LEVEL TOOLS

To present the evaluated models, these were separated in bibliometric characteristics: year of publication and journals used to disseminate the work; and finally a number of other features concerning each model. These will be detailed in the following sections.

Bibliometric Analysis

Analyzing the models' year of publication, in Figure 1 we can see that there is a growing trend, but it is not uniform. The significant drop in recent years may be due to the maturity of the area, yet the recently published models have no similar characteristics as can be seen in Table 3, which means it did not occur to theme saturation. This fact can be confirmed by this high variability, indicate that there is not a consensus in the literature on best practices in this field.

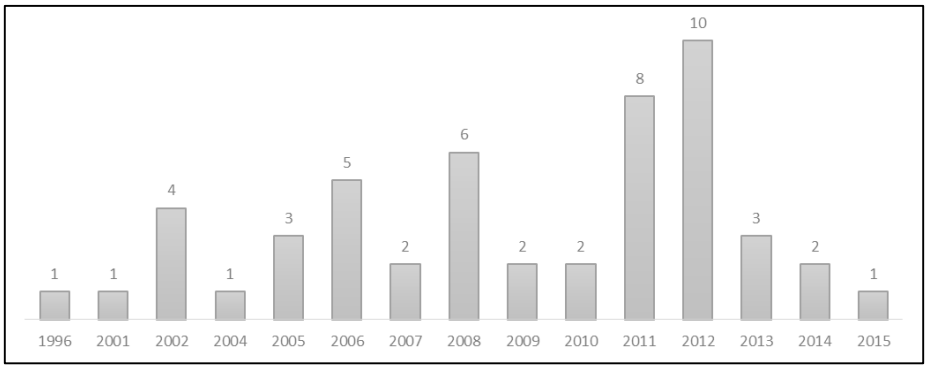

Figure 1 – Publication distribution per year

With regard to the journals, as we can see in Figure 2, the 51 models are contained in 34 different journals. The International Journal of Advanced Manufacturing Technology is the journal with the greatest number of publications, followed by International Journal of Production Operations and Management, totaling 25% of the publications. There is no significant concentration of publications, which hinders the knowledge spread, since there is not a journal, or even a group of journals, that are reference to this field.

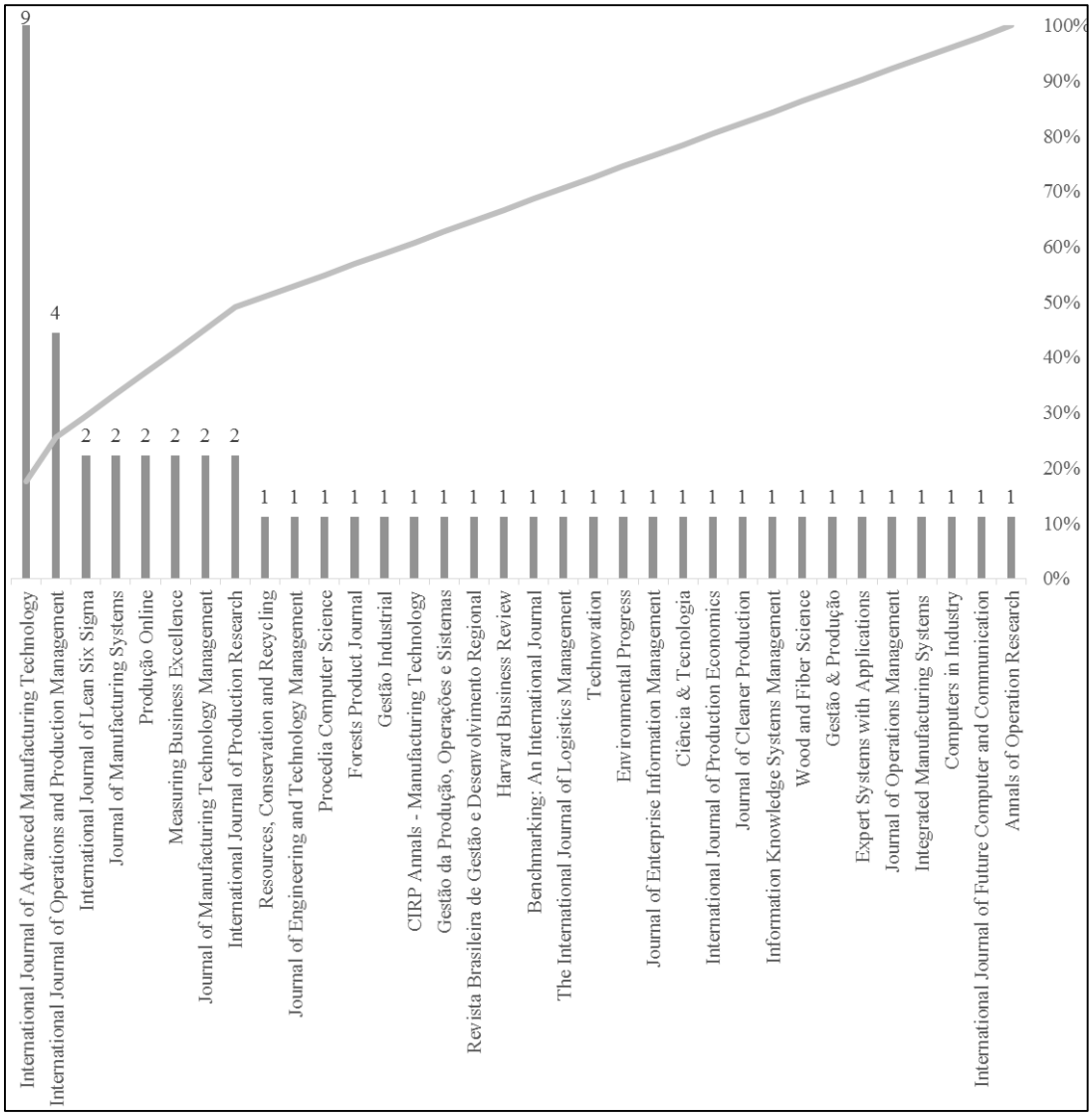

Figure 2 – Publication distribution per journal

Evaluation of the Models

As a way of assessing the models found in the systematic literature review, we designed some questions that are presented in Table 3, in order to create meaningful comparison of items for the models' study. Moreover, the questions presented can also be used for verifying possible opportunities to develop a new model for evaluation.

Table 3 – Evaluating of the models.

#	**Question**	**Legend**
A	Does the model have maturity levels? If yes, how many?	Y=Yes; N=No
B	What is the valuation method used?	A=auditing; C=Checklist; F=Fuzzy; S=Survey; O=Other

C	What is the model approach?	T=Quantitative; L=Qualitative; B=Both; na=Not Applicable
D	Did the authors conduct model applications in real cases?	Y=Yes; N=No
E	Was there confirmation of the data? (search for evidence at more than one source)	Y=Yes; N=No; na=Not Applicable
F	Does the model have defined indicators?	Y=Yes; N=No; na=Not Applicable
G	In the evaluation, are they contemplating items beyond the shop floor?	Y=Yes; N=No; na=Not Applicable
H	Are there items relating to human resources? (focused on the commitment of people)	Y=Yes; N=No; na=Not Applicable
I	Are there items related to the Lean philosophy and corporate culture?	Y=Yes; N=No; na=Not Applicable; cc=Corporate Culture Only
J	Does the model propose future improvements?	Y=Yes; N=No; na=Not Applicable
K	Do the authors provide data to replicate the model?	Y=Yes; N=No; na=Not Applicable

Models	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Karlsson and Ahström (1996)	N	C	L	N	na	Y	N	N	N	N	Y
Sánchez and Pérez (2001)	N	C	B	Y	N	Y	N	N	N	N	Y
Goodson (2002)	5	S	B	N	na	Y	Y	Y	N	N	Y
Kumar and Thomas (2002)	N	C	B	N	na	Y	N	N	N	N	Y
Soriano-Meier and Forrester (2002)	N	S	T	Y	Y	N	Y	N	N	N	N
Nightingale and Mize (2002)	Y	C	B	Y	N	Y	Y	Y	N	Y	Y
Kojima and Kaplinsky (2004)	9	C	B	Y	N	Y	Y	N	N	N	Y
Cardoza and Carpinetti (2005)	N	C	B	Y	N	Y	N	N	N	N	Y
Doolen and Hacker (2005)	5	S	B	Y	N	Y	Y	N	N	N	N
Dos Reis and Barros (2005)	N	C	B	Y	Y	Y	Y	N	N	N	Y
Taj (2005, 2008) and Taj and Morosan (2011)	5	C	B	Y	N	Y	Y	N	N	N	Y
Bonavia and Marin (2006)	N	C	B	Y	N	Y	N	N	N	N	Y
Cumbo, Kline and Bumgardner (2006)	N	S	na	N	na	N	N	N	N	N	N
Lucato, Maestrelli and Vieira Junior (2006)	4	C	B	N	na	Y	Y	Y	cc	N	Y
Ray *et al*. (2006)	N	C	T	Y	Y	Y	N	N	N	N	Y
Srinivasaraghavan and Allada (2006)	N	S	T	Y	N	Y	N	N	N	Y	Y
Matsui (2007)	N	S	B	Y	Y	Y	Y	N	N	N	N
Shah and Ward (2007)	N	S	B	Y	N	Y	Y	N	N	N	Y
Bayou and Korvin (2008)	3	F	B	Y	N	Y	Y	N	N	N	Y
Dias, Fernandes and Godinho Filho (2008)	N	C	B	Y	Y	Y	Y	N	N	N	Y
Do Valle *et al*. (2008)	N	C	B	Y	N	Y	Y	N	N	N	Y
Nogueira and Saurin (2008)	N	C	B	Y	Y	Y	Y	Y	cc	N	Y
Saurin and Ferreira (2008)	N	C	L	Y	Y	Y	Y	N	N	N	Y
Wan and Chen (2008)	N	O	T	N	na	N	N	N	N	N	Y
Gurumurthy and Kodali (2009)	N	A	B	Y	Y	Y	Y	N	N	N	Y
Wan and Chen (2009)	N	S	na	N	na	Y	Y	na	na	Y	N
Rahman, Laosirihongthong and Sohal (2010)	N	S	L	Y	N	Y	N	N	N	N	Y
Singh, Garg and Sharma (2010)	N	O	B	N	na	N	Y	N	N	N	Y
Behrouzi and Wong (2011)	N	F	T	N	Y	Y	N	N	N	N	Y
Bhasin (2011)	7	A	B	Y	Y	Y	Y	Y	Y	Y	Y
Eswaramoorthi *et al*. (2011)	N	S	B	Y	N	Y	Y	Y	Y	N	Y

Hofer *et al*. (2011)	N	S	B	N	na	N	Y	N	N	N	N
Seyedhosseini *et al*. (2011)	N	O	B	N	na	Y	Y	Y	N	N	Y
Vinodh and Balaji (2011)	N	F	L	Y	N	Y	Y	N	N	Y	N
Vinodh, Prakash and Selvan (2011)	N	F	B	Y	N	N	Y	N	N	N	N
Anvari, Zulkifli and Yusuff (2012)	N	O	L	Y	N	N	N	N	N	N	Y
Azevedo *et al*. (2012)	N	C	L	Y	Y	Y	Y	N	N	N	Y
Bhasin (2012)	N	S	B	Y	Y	N	Y	Y	Y	N	N
Chauhan and Singh (2012)	N	S	L	Y	N	Y	Y	Y	cc	N	Y
Cil and Turkan (2012)	N	O	L	Y	Y	N	Y	Y	Y	N	N
Nasab, Bioki and Zare (2012)	3	O	L	Y	N	N	N	N	N	N	N
Unver (2012)	N	O	T	Y	Y	Y	N	N	N	N	N
Vinodh and Vimal (2012a)	N	F	L	Y	Y	Y	Y	Y	Y	Y	Y
Vinodh and Vimal (2012b)	N	F	L	Y	Y	Y	Y	N	N	Y	N
Zhou (2012)	3	S	L	Y	N	N	Y	Y	Y	N	N
Campos (2013)	5	C	L	Y	Y	Y	Y	Y	cc	Y	Y
Diaz-Elsayed *et al*. (2013)	N	O	B	Y	Y	N	N	N	N	N	N
Malmbrandt and Ahlstrom (2013)	5	C	L	N	na	Y	Y	Y	N	N	Y
Kundu and Bairi (2014)	N	S	B	N	na	N	Y	N	N	N	N
Wong (2014)	N	O	L	N	na	N	na	na	na	N	N
Maasouman and Demirli (2015)	4	C	B	Y	Y	Y	Y	N	N	N	Y

It is possible to check for example that just 6 of the 51 models evaluates the aspect of lean philosophy, and only 4 look for corporate culture. However, this is a superficial evaluation, and this issue can be better explored, because this aspect is considered by several authors, as: Shah and Ward (2007), Bhasin (2011) and Fullerton et al. (2014); like an essential and decisive item for the successful implementation of lean in companies. There are a considerable number of publications that evaluate only the shop floor, not the company as a whole, as defended by Ohno (1997) that this philosophy must be disseminated throughout the organization. So, we can conclude that there is still gaps for the creation and improvement of models for assessing the lean maturity in companies.

TOOLS FOR PERFORMANCE ANALYSIS

We also carried out an analysis of methods that assess the lean maturity of the models found in the literature review; the results are shown in Figure 3. We identified four main methods: Evaluation by: checklists - which was the more used method-, survey with several companies, application of fuzzy logic and conducting audits. Yet there were other methods, such as computer simulation and neural networks analysis, identified which were less representative.

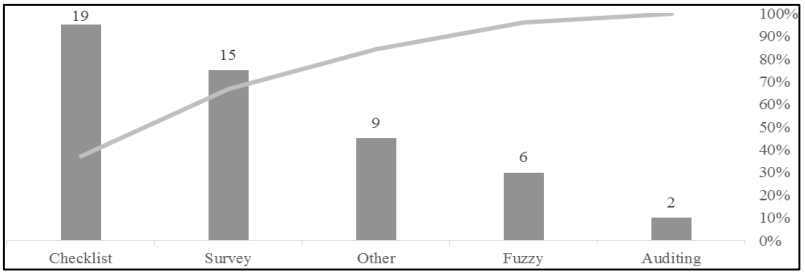

Figure 3 – Used evaluation methods

Among the methods, the audit was more complete because, unlike the survey and in some cases of checklist and even the application logic Fuzzy, where data is collected from a single source like interviews, questionnaires or either data from the enterprise information system, the audit verifies, or should verify, data from multiple sources of information. It brings more reliability to the findings.

CONCLUSION

Through all the presented results we can conclude that this issue is very studied and discussed, but there is still no consensus as to which is the best evaluation method, which are items that must be evaluated, what are the best practices, or the evaluation scope that should be considered. Thus, there is a large gap to the new models development, reinforced by poor rating of the presence and spread of lean philosophy in corporate culture, aspect observed by the literature as critical to the successful of lean implementation.

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