How to assess the degree of leanness: a preliminary proposal.

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Abstract: Since its initial developments, lean production has been recognized as a paradigm able to standardize processes, provide long-term benefits and open up new strategic opportunities. Nowadays literature acknowledges that process orientation and waste elimination promoted by lean production are among the enabling conditions towards Industry 4.0, considered the crucial paradigm for meeting current and future market requirements. Implementing tools and practices of lean production has even increased its importance. In this context, assessing the lean implementation level of a company is valuable for two reasons: first, it helps companies interested in Industry 4.0 to evaluate the existence of enabling conditions; second, it helps researchers to identify directions for an effective adoption of the paradigms. Due to these reasons, the present paper aims at providing a review and classification of leanness assessments in literature based on a categorical analysis suggested by Narayanamurthy and Gurumurthy (2016), at identifying their limitations (for instance focus on a specific industrial sector or a unique case study or lack of an empirical test) and possible strengths (such as benchmarking or use of scale) and at proposing a new leanness assessment tool able to overcome the limitations and to include the strengths.

Keywords: lean assessment, leanness assessment, literature review, assessment tool, leanness.

1.Introduction

Numerous studies on lean production (LP) have stated several tangible benefits, from its initial purpose in removing any inconsistency and waste (Jasti & Kodali, 2015) to the increasingly topical possibility to open up new strategies (Drew et al., 2004). LP is able to reduce human effort, space, inventory, costs and to result in higher quality, fewer defects and more on-time-delivery (Ramesh & Kodali, 2012; Pozzi et al. 2015; Cannas et al. 2018). Beyond manufacturing sector, LP's benefits have encouraged its application in processes industries and service such as logistics, retail, distribution, healthcare and public administration (Jasti & Kodali, 2015). In all the sectors the LP principles' implementation has been successful: process industries that apply LP techniques benefit from lead time reduction, release of working capital and performance improvements across the whole supply chain as well as manufacturing industries (Melton, 2005; Panwar et al., 2015; Pozzi et al., in press); also in the service sector there is the evidence of benefits such as waste elimination, economic and financial results improvements, lead time reduction and the introduction of continuous improvement as a cultural element (Hadid & Afshin Mansouri, 2014; Leite & Vieira, 2015). Despite these benefits, nowadays LP is struggling against to the highly customized products demand (Kolberg et al., 2017) resulting in increasingly complicated management systems such as single-machine multi-item ones (Rossi et al. 2017) and the consequent need for new infrastructures to manage the increased data volume and the real-time availability. Industry 4.0 (I40) is the new paradigm able to overcome LP's limits, making the processes more transparent and flexible and to bring LP at the cutting edge. A link of mutual support between I40 and LP is recognized (Mrugalska & Wyrwick., 2017; Kolberg & Zuehlke, 2015; Wagner et al., 2017 Dombrowski et al, 2017). For instance, due to the use of sensor system and RFID, I40 can improve the Kanban system, shorten cycle time, and make milk-runs more efficient. I40 can boost JIT/JIS-systems since bullwhip effects are reduced and a cloud-based ERP system makes the whole process highly transparent and integrated and leads improvements in production planning (Hofmann & Rüsch, 2017). On the other hand, the automation and information exchange that characterized I40 need an efficient definition of processes before their implementation; they require an high process orientation with defined tasks and times, hence LP can be considered a prerequisite (Dombrowski et al., 2017). LP creates the right environment and supports the installation of I40, indeed the standardization and optimization led by LP can lower risks of integration (Kolberg & Zühlke, 2015). The research of Tortorella and Fettermann (2017) confirmed these statements analyzing data from 110 companies of different sectors and different levels of LP implementation. Their evidences suggested that I40 is significantly associated with the level of implementation of LP practices. Hence, in order to create the right context for I40 adoption, there is the need to improve lean transformation. To the aim of selecting the lean techniques able to promote lean transformation, the use of a leanness assessment (LA), the instrument for evaluating the stage in the lean transformation and to create a framework for improvement (Liker, 1997), is needed. Such a LA helps in evaluating the current implementation level of lean tools and techniques and the actual step in the lean journey, but it could also suggest how to reach the wanted position, indicating, according with the goals of the firms, which areas should be improved. A LA could also be helpful in identifying the right timing for the LP techniques and tools application. For instance, Browning and Heath (2009) highlighted that a not timely consideration of techniques could lead to unexpected effects. For example, the use mistake-proofing tools before an overall stabilization of the processes are reached can prove to be not cost-effective because the general environment is not ready. Notwithstanding the importance of a widespread adoption of LP practices and tools is acknowledged and the concept of LP is fully defined in the literature, the approach to assess its adoption has still not been (Pilkington and Fitzgerald, 2006), indeed there are several methodologies. The aim of this paper is to gain an overview of the different ways of assessing lean implementation presented in literature, identifying their strengths and limitations and to develop a preliminary proposal of a new model that includes the identified strengths and, at the same time, overcomes the most assessed limitations. In particular, the proposed LA is based on a checklist able to assess LP implementation over the four main "house of lean" (Stehn & Höök, 2008) areas, i.e. stability, culture, quality and just in time, providing a complete point of view.

The paper is organized as follows. The next section is devoted to the review of literature on LA, presenting the outcomes of previous review on the topic, giving details on the reviewed papers collection and on the methodology of papers classification and discussing the output. In the third section, a preliminary proposal of a new model of LA aimed at including the strengths and at overcoming the limitations found in the review of literature is presented. Future research steps will be presented in the last section.

2. Literature review

According to Narayanamurthy and Gurumurthy (2016), their literature review is the only work that perform a comprehensive review on the topic of "leanness assessment" up to 2014. Their comprehensive review revealed that (i) 87% of papers focused on manufacturing firm. As stated by Azadeh et al. (2015), LA tested in a single sector can contain an industrial bias and may not cover all possible dimension. (ii) They highlighted that majority of the studies are quantitative. However, thanks to the least mathematical complexity, qualitative LA are recently increasing. (iii) There was a minority of conceptual studies. The limitation of conceptual studies is connected to the ability of acquiring awareness of their weaknesses and strengths and, moreover, it limits the gain of practical evidence as improvement suggestions. (iv) Only 17% of the papers adopted multiple case studies. Testing the model in only a single company can bring to tailored adjustments and corrections of the assessment tool, limiting the possibility of its application to a broader panel. (v) Most of the studies use survey-questionnaire or checklist to collect data and experts' evaluation and rating through question (for instance in fuzzy method LA), can be taken into this category. The immediacy of this kind of data collection make managers more willing to perform LAs. (vi) Most of the paper used scales, that can facilitate the LA interpretation, like Likert o Saary's scales. It was noticed that a scale for assessing lean in service organizations is missing. (vii) A minority of papers used benchmarking while assessing lean transformation, but benchmarking provides clear and objective standards for understanding the leanness level. (viii) Most of the quantitative studies developed an index as a measure of leanness that can be a fuzzy index, a lean performance score or a leanness score. These studies have the ability to benchmark the extent of leanness in future research. There is a lack of leanness index among LA for service sector. (ix) They stated that reasons behind the choice of different LA methodologies is lacking in the existing literature , but they observed that majority of articles used fuzzy method- based LA. All other techniques were used in less than two papers, probably for the complexity of the method itself or of the needed input data. According to this overview, the present work aims at investigating whether more recent works on the topic overcome the limitations and confirm the strengths found by Narayanamurthy and Gurumurthy (2016).

2.1 Papers collection and Methodology

The papers to be reviewed were gathered from the database Scopus starting with an "AUTHKEY", i.e. the keywords assigned by the authors to a document, search using the keywords suggested by Narayanamurthy and Gurumurthy (2016), namely "lean assessment", "lean evaluation", "lean measurement", "lean quantification", "degree of leanness", and "leanness". The keyword "maturity model" was added because the meaning of maturity, i.e. the accomplishment of a target from an initial to a desired stage (Mettler & Rohner, 2009), is exactly what a LA should evaluate. In addition, a cross-referring approach was adopted to find other relevant papers. As Narayanamurthy and Gurumurthy (2016) considered articles published until January 2014, the present research considers papers published from January 2014 to March 15, 2018. Particular attention should be paid to the meaning of the words "lean" or "leanness", which can be intended with meanings different from LP and connected with medical fields, such as Chemistry, Nursing, Medicine, Veterinary etc., therefore all these subject areas were excluded, so that the remaining areas are: "Engineering", "Business, Management and Accounting", "Computer Science" and "Decision Sciences". The result of the selection process was of 50 papers (29 articles, 19 conference papers, 1 article in press and 1 review). Considering only the articles and reading all the abstracts, 10 were excluded because their research question was not addressed in evaluating the degree of leanness by a LA tool and two (Saleeshya and Veda Vyass, 2017; Garbie, 2017) were not accessible. Using the cross-referring approach, other 10 relevant papers were selected. In total, this literature review takes into consideration 27 papers. All the papers were read and analyzed through a categorical analysis (table 1) according to the categories suggested by Narayanamurthy and Gurumurthy (2016).

2.3 Categorical analysis

The performed categorical analysis is summarized in the following table (table 1). It is evident an increasing trend for practical studies, indeed only 3 out of 27 studies are conceptual. Papers that provides a numerical index are quantitative studies and they are the majority. Single case studies are still the most used method to test LAs.

Manufacturing sector is still the most studied one, indeed only 3 studies referred to service sector (2 to healthcare and one to administration). Among the papers, there aren't references to process sector, except for Lucato et al. (2014). The use of questionnaires to collect data is confirmed as the preferred one, perhaps for the ease of interpretation of close-ended questions. It is evident that new methodologies are trying to emerge, but fuzzy method, that combines non-numerical elements, such as linguistic variables, and numerical translation, is still the most adopted. The numerical index is a fuzzy index for all the fuzzy method based or fuzzy related LA, and it is a leanness score for the other studies. Benchmarking can be referred to a comparison with other companies, such as the comparison with the value stream of the partners considered by Narayanamurthy and Gurumurthy (2016), between methodology results (Sharma and Shah, 2016), with normative standards (Lucato et al. 2014), with best practice (Chiu and Chiu, 2017), with self-stated "to be" scenario (Guimarães and Carvalho, 2014; Balaij et al. 2016), or self-stated standards declared to guide the evaluation.

Table 1. Categorical analysis (I)
(M; manufacturing sector; P: process sector; S: service sector; B: benchmarking; NI: numerical index)

Paper	Organization type	Methodology adopted
Almomani et al. (2014)	M (furniture)	AHP
Matawale et al. (2014)	M (locomotive part)	Fuzzy method
Wong et al. (2014)	M (semiconductor)	ANP
Maasouman and Demirli (2015)	M (two manufacturing cells)	Score based on Visual-data driven checklist
Matawale et al. (2015)	M (automotive company-focus on its supply chain)	Fuzzy method
Matawale et al. (2015)	M (auto part)	Fuzzy method
Seyedhosseini and Ebrahimi (2015)	M (auto part)	Group fuzzy analytic network process (GFANP)
Ali and Deif (2016)	M (kitchen equipment)	System dynamics approach
Maasouman and Demirli (2016)	M -	Fuzzy method
Narayanamurthy and Gurumurthy (2016)	M -	Graph-theoretic approach
Sharma and Shah (2016)	M (warehouse of a fiber manufacturing firm)	Real time Delphi - ANP
Vidyadhar et al. (2016)	M (relays and transformers)	Fuzzy method
Thomas et al. (2017)	M (tyre)	AHP, ISM
Tortorella et al. (2017)	M (auto part)	Weighted average
Narayanamurthy and Gurumurthy (2017)	S (hospital)	Fuzzy method
Balaji et al. (2018)	M (rubber and mechanical equipment)	TOPSIS- Simos (to find the LRE, who determines leanness level)
Al-Ashaab et al. (2016)	M (aerospace, automotive)	Score average/ as is – to be comparison
Laoha C. and Sukto S. (2015)	M (shoe and garment)	Score average
Elnadi M. and Shehab E. (2016)	M (document management, train, commercial heavy vehicles)	Weighted score
Liu C.-C. et al.(2017)	M (auto part, transmission and communication tower, steel wire)	Fuzzy method, TOPSIS
Rajpurohit1 (2017)	M (submersible pumps, healthcare products)	Fuzzy method, TOPSIS
Azadeh et al. (2015)	M (packing and printing)	DEA, fuzzy method, DEMATEL, AHP
Chiu and Chiu (2017)	M (used car)	Rapid plant assessment, Kruskal-Wallis and Wilcoxon tests
Lucato et al. (2014)	M/P (automotive, metal-mechanical, abrasives, furniture, etc.)	DOL-SAE J400 standards, t-test, one-way ANOVA
Năftănăilă and Mocanu (2014)	S No test (office – admin. area)	score Radar chart
Pakdil and Leonard (2014)	No test	LAT, fuzzy method, radar charts
Guimarães and Carvalho (2014)	S No test (health center)	Scores – "as is" diagnosis tool

Paper	Data collection method	B	N I
Almomani et al. (2014)	Single case study Questionnaire		x
Matawale et al. (2014)	Single case study Experts' evaluation		x
Wong et al. (2014)	Single case study Experts' evaluation		x
Maasouman and Demirli (2015)	Single case study Checklists		x
Matawale et al. (2015)	Single case study Experts' evaluation		x
Matawale et al. (2015)	Single case study Experts' evaluation		x
Seyedhosseini and Ebrahimi (2015)	Single case study Experts' evaluation		x
Ali and Deif (2016)	Single case study Measurement (WIP efficiency, OEE, service level)		x
Maasouman and Demirli (2016)	Single case study Checklist		x
Narayanamurthy and Gurumurthy (2016)	Single case study 5 point Likert scale and 9 point Saaty scale	x	x
Sharma and Shah (2016)	Single case study Real time Delphi - survey	x	x

Vidyadhar et al. (2016)	Single case study Experts' evaluation		x
Thomas et al. (2017)	Single case study Expert's evaluation (Saaty's scale)	x	
Tortorella et al. (2017)	Single case study Questionnaire		x
Narayanamurthy and Gurumurthy (2017)	Single case study Observations and interviews	x	x
Balaji et al. (2018)	2 cases Questionnaire, alternatives choices	x	
Al-Ashaab et al. (2016)	2 cases as is- to be questionnaire SAUCE scale	x	
Laoha C. and Sukto S. (2015)	8 cases Survey with an ADLI score system	x	x
Elnadi M. and Shehab E. (2016)	3 cases semi-structured interview to academician and experts		x
Liu C.-C. et al.(2017)	3 cases Experts' evaluation (Delphi method)		x
Rajpurohit1 (2017)	3 cases Experts' evaluation		x
Azadeh et al. (2015)	40 cases Experts' evaluation - questionnaire		x
Chiu and Chiu (2017)	42 cases Interviews, field study and documentation	x	x
Lucato et al. (2014)	51 cases Questionnaire (DOL-SAE J400 standards)	x	x
Năftănăilă and Mocanu (2014)	Questionnaire		x
Pakdil and Leonard (2014)	quantitative LA: KPI; qualitative: 5-point Likert scale survey		x

According to the performed categorical analysis, the limitation identifiable within the collection of papers reviewed by Narayanamurthy and Gurumurthy (2016) are confirmed in the following papers. Among the reviewed papers, the most completed seems to be the one by Maasouman and Demirli (2015) that proposed a visual data-driven LA whose framework based on grounded lean principles. However, data collection process of their model can be long because of the huge amount of required data, moreover they mainly focus on tools and practices application convertible on percentage. In light of this evidences, there is the need of a new LA, able to overcome the mentioned limitation and to perform a complete, easy and objective assessment.

3. New leanness assessment model

The model presented in this section is a visual and data driven checklist based on a Likert scale. In order to design a LA model applicable to any organization type and industry, finding a common framework that characterizes LP implementation is needed. The "house of lean", a distinctive and visual model first created by Taiichi Ohno and Eiji Toyoda at the Toyota Motor Company (Stehn & Höök, 2008) distinguishing four areas (Stability, Quality, Just in Time and Culture) of LP tools and practices, represents the reference framework of the proposed assessment. Among the plethora of LP tools and practices (Doolen & Hacker 2005; Ciarapica et al. 2014) the selection of the ones addressing the four areas is performed with the help of Lean experts (table 2) **.**

Table 2. framework of the leanness assessment model

Areas	LP tools and practices
Stability	5s, SMED, TPM, Standard Work, Visual Management
Quality	Jidoka, Poka Yoke, Prevention, Problem Solving
Just in Time	Heijunka, Flow production, Pull-Kanban-Synchro, Supplier Integration
Lean Culture	Kaizen, HR management, Leadership Commitment

The experts identified also the 48 items, i.e. proxies of the effects of tools/practices implementation, to evaluate the level of implementation of selected LP tools and practices (table 3). They also assigned a corresponding importance weight from 1 to 3 to all the items for each sector according to their typical suitability (table 3). The assessment consists of a visual and data driven checklist that associates to each item five pictures or ranges of values (corresponding to 10 Likert-scale) corresponding to levels of implementation, to be compared with the actual implementation. The use of a visual system is suitable for techniques that have a tangible impact, such as 5s (figure 1). Of course soft factors, such as HR management, cannot be compared to a visual benchmark, but the same framework were used to provide a clear textual description of the criteria necessary to obtain a certain score (e.g. the bottom of figure 1, 2 and 3). These clear descriptions allow to assign a score on reaching a goal even in more complex context such as SMED projects (figure 2) and Kanban application (figure 3). Likert scale substitute a rate for an agree/disagree judgement providing numbers (Allen & Seaman, 2007), hence the combination of visual references, judgments and numerical scores makes the assessment semi-quantitative. The pictures and the ranges of values corresponding to the implementation levels are gathered from real processes with the help of experts and their use sets standard references, facilitating the conduction of the experts assessment and the impartiality of self-assessment by companies. The comparison between the checklist benchmark and the real situation should be carried out visiting the plant, using the "gemba walk" (Womack, 2010).

Table 3. LP practices, items and corresponding sector importance weight (M; manufacturing sector; P: process sector; D: distribution sector)

LP tools/ practices	items	weight		
		M	P	D
5s	Order,	3	3	3
	cleanliness,	3	3	3
	right materials' allocation	3	3	3
SMED	Standard of setup,	3	3	1
	setup time reduction activity	3	3	1
TPM	Type of maintenance,	2	3	0
	maintenance process and documentation,	2	3	0
	autonomous maintenance,	2	3	0
	state of machineries	2	3	0
Standard work	Ergonomic workstation,	3	2	3
	standardized work procedures,	3	2	3

	production and quality control specifications	3	3	3
Visual management	Information display,	3	2	3
	Andon warnings,	3	2	0
	warnings of no compliance,	3	3	3
	shop floor management	3	2	3
Jidoka	Jidoka machineries,	3	2	1
	jidoka workers	3	3	3
Poka yoke	Poka yoke procedures,	3	3	3
	poka yoke materials	3	3	3
Prevention	Self-control of the suppliers,	3	1	3
	suppliers indicators of managements,	3	1	3
	statistical process control,	3	3	3
	customers' voice	3	1	3
Problem solving	Problem solving groups,	3	3	3
	quality groups	3	3	3
Heijunka	Leveled production,	3	1	3
	flexibility of the production tools,	3	2	0
	production change ease,	3	3	0
	workforce flexibility	3	2	3
Flow production	One piece flow,	3	1	3
	layout,	3	2	3
	materials' flow,	3	2	3
	flow visibility,	3	2	3
	warehouse position	3	2	3
Pull-Kanban-Synchro	Kanban areas,	3	3	3
	procurement logic for the production areas,	3	2	3
	materials distribution	3	1	3
Supplier integration	Material planning and control,	3	1	3
	partnership contracts with suppliers,	3	1	3
	suppliers location and milk-run	3	1	3
kaizen	Internal continuous improvement,	3	3	3
	continuous improvement with suppliers	3	1	3
HR management	Staff's turnover,	3	3	3
	training,	3	3	3
	incentives	3	2	3
Leadership commitment	Communication,	3	2	3
	lean plan (hoshin kanri)	3	2	3

A LP tool/practice implementation level is given by the weighted average of all corresponding items implementation level values. An area's leanness level is given by the average of the implementation level of related LP practices. The average of all the 16 practices' implementation level gives the overall leanness level. The evaluation is also a diagnosis tool that suggests if an action is needed, indeed 0 means "an action is urgent" and 10 "sustain". It helps in identifying the strongest and weakest area driving management decisions. The overall leanness level index can be used as comparison standard for the next LA in order to verify if the general improvement strategies succeeded and whether and how an action on a particular area affected the total leanness.

The presented LA model was successfully tested in a heterogeneous panel of 28 companies of different size, precisely 11 manufacturing firms, 7 process firms and 6 distribution companies. The first LAs were performed last year by LP experts who spent half a day in each plant assessing all the items of the checklist during the gemba walk. Some managers of those companies replicated the LA by themselves this year, demonstrating its power even as self-assessment tool.

Figure 1. Example of visual guide for 5S (example for the first item, i.e. order)

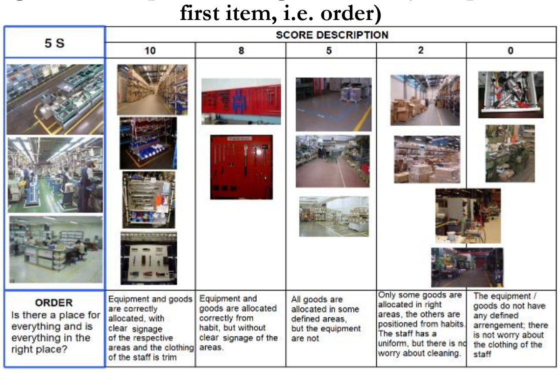

Figure 2. SMED guide (example for the first item, i.e. standard of setup)

SMED-RTS	SCORE DESCRIPTION				
	10	8	5	2	0
STANDAR OF SET UP Are there written and standardized set up procedures?	There are written, standardized and known procedures of the production equipment set up and of verification of the set up itself.	There are written and standardized procedures of the production equipment set up and of verification of the set up itself, but not properly known	There are procedures of the production equipment set up and of the verification of the set up itself, but only orally transmitted	There are procedures of the production equipment set up, but there are NOT procedures of verification of the	There are NOT any set up procedures

Figure 3. Pull-kanban-Synchro guide (example for the first item, i.e. kanban areas)

PULL-KANBAN-SYNCHRO	SCORE DESCRIPTION				
	10	8	5	2	0
Are there areas for the material flow control able to guarantee the phases balance?	The structured KANBAN areas are used as signals of work and of advancement of the product along the productive process	The structured KANBAN areas are used only as work signals	The structured KANBAN areas are used partially and only as work signals	There are very few structured KANBAN areas and only partially used as work signals	KANBAN areas are not used at all

4. Conclusion

Lean transformation is recognized as a topic of current interest, due to its positive effect on the successful adoption of I40 technologies (Tortorella & Fettermann, 2017), and, as well LA is recognized as a guiding tool to lean transformation (Liker, 1997). According to the findings by Narayanamurthy and Gurumurthy (2016) and to the performed review, a LA, in order to overcome previous studies limitation and to confirm their strengths, should be a practical study, tested in a multiple cases and sectors context, with an easy data collection methodology, including a focus on different aspects and preferably characterized by a scale, a benchmarking reference and the providing of a final numerical index. The proposed LA includes all these features. It is a semi-quantitative, practice grounded LA that involves 28 firms characterized by different size and sector, including manufacturing firms, process industries and distribution companies, preventing any industrial bias. The use of a visual and textual benchmark makes the assessment objective and reliable and the use of a Likert scale add clearness. The "house of lean" framework behind the model makes it applicable in every context and can facilitate the identification of the area that needs improvement actions. Referring to the grounded principles of LP, it assesses also behavioral aspects such as the leadership commitment. The numerical indexes that describe the implementation level of practices, the leanness of an area and the overall leanness, can be used as diagnosis elements and benchmark for future assessments. The proposed LA is then easily repeatable over time, facilitating the evaluation of the effect of the improvement strategies on the lean transformation and longitudinal studies. A possible stream for future research is the study of the results of the proposed LA in those companies which are implementing I40 to investigate further the relationship between the leanness level and I40 and its enabling lean techniques.

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