Management Decision

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Received 25 January 2017
Revised 9 April 2017
13 June 2017
Accepted 5 July 2017

Abstract

Purpose – The purpose of this paper is to define the individual leadership competencies that are necessary to implement and sustain lean systems, based on a multi-method approach.
Design/methodology/approach – Data collection involved a literature review of lean competencies, interviews with four experts from the university and the industry, and an empirical survey answered by 91 respondents, who represented companies from several sectors. These techniques provided a mix of qualitative and quantitative data, which set a basis for identifying a list of competencies and discussing its validity.
Findings – In total, 16 lean leadership competencies were identified and validated, in terms of content validity, face validity, and predictive validity. Regarding this latter validity type, the survey results indicated that the competencies are positively associated with key operational performance indicators, organizational maturity level of lean, and leaders' experience with lean systems.
Practical implications – The identified list of competencies may be a basis for the development of formal lean leadership development programs. The list may also support the design of tools for assessing the competencies of leaders in lean companies.
Originality/value – A list of 16 lean leadership competencies was developed based on a verifiable research method that used a mix of data collection techniques. This methodological approach is a distinctive characteristic in comparison with earlier studies, which did not include an empirical validation of the competencies.

Keywords Leadership development, Leadership, Behaviour, Lean production

Paper type Research paper

1. Introduction

Although the importance of leadership has been recognized implicitly since the early descriptions of the Toyota Production System (TPS) (Sugimori *et al.*, 1977; Monden, 1998; Schonberger, 1982), the understanding of TPS was focused on the tools and techniques (Shah and Ward, 2003).

Lean Production Systems (LPS), originated from the TPS, have been adopted in several sectors, and their implementation involves various difficulties as well as organizational changes (Nordin *et al.*, 2012; Achanga *et al.*, 2006). Among these difficulties, those related to leadership are frequently mentioned (Marodin and Saurin, 2015a; Alagaraja, 2014).

Emiliani (2003) argues that LPS philosophy and principles require that leaders have particular behaviors and competencies. In another study, Emiliani and Stec (2005) argue that lean organizations should be managed based on certain beliefs that drive the behaviors, which, in turn, are associated with managerial competencies.

Nevertheless, many publications about leadership in an LPS (Liker and Convis, 2012; Spear, 2004) have not been carried out as academic research and are mostly based on their authors' own experiences. Other studies, despite pointing toward leadership characteristics, such as behaviors, attitudes, roles, and responsibilities, (e.g. Emiliani, 2003;

Management Decision
Vol. 55 No. 10, 2017
pp. 2163-2180

0025-1747
DOI 10.1108/MD-01-2017-0045

Emiliani and Stec, 2005; Liker and Ballé, 2013), do not present a verifiable research method to support their findings.

Thus, some knowledge gaps have not yet been addressed from a scientific perspective supported by empirical research. This criticism applies, for instance, to the identification of competencies of leaders involved in LPS. As another drawback, lean leadership studies supported by empirical data are mostly case studies (e.g. Liker and Ballé, 2013; Spear, 2004). This hinders generalizations about findings related to what the lean leadership characteristics are. Furthermore, there is a lack of empirical evidence linking the level of leaders' competencies development and operational results.

In order to address these gaps, this study aims to identify and validate the necessary competencies to perform the lean leadership role. Boyatzsis (2008) defines competency as a capability or ability, and describes it as a set of related but different behaviors organized around intentions. Behaviors are manifestations of the intent, as appropriate in various situations (Boyatzsis, 2008). According to the same author, a competency requires both actions and intentions, which can be inferred from the observable behaviors. Therefore, the research question investigated in this study is stated as follows:

RQ1. What are the leadership competencies required to support an LPS implementation?

This question is investigated based on a multi-method approach, which provided a mix of qualitative and quantitative evidence. In this study, we assume that competencies mentioned by several authors of TPS, like Spear (2004), Liker and Convis (2012), Liker and Ballé (2013), are relevant for lean, since it was originated from that production system, and considered as the LPS literature.

2. Literature review

2.1 Leadership in an LPS

Although the topic of leadership in organizations has been studied for over 50 years (Yukl, 2010), the focus on leadership in LPS is relatively recent (Found and Harvey, 2007). Indeed, many recent studies have spotted effective leadership as a critical factor for a successful lean implementation (Marodin and Saurin, 2015a; Alagaraja, 2014). Table I presents an overview of the literature about leadership in LPS.

Table I indicates that the selected publications whose main topic is leadership are either descriptions of cases or theoretical studies. It also indicates that most of the studies are focused on the manufacturing industry, which may have an influence on the relative importance of the competencies and ways of deploying them. In addition, 50 percent of the publications approach leadership as a critical factor for LPS, highlighting the distinctive roles and responsibilities of leaders in lean systems. Lists of leadership behaviors or competencies are presented in two papers (Emiliani, 2003; Emiliani, 1998). As a drawback, in both studies, Emiliani neither specifies how the lists of behaviors and competencies were identified, nor does he empirically validate the lists.

3. Research method

3.1 Overview

This research was divided into four sequential steps: a literature review to develop a preliminary list of competencies and their descriptions; a refinement of these descriptions with lean experts; an analysis of the level of agreement of these competencies with core lean principles; and an empirical validation of these competencies with a fairly large sample of practitioners.

Validity is a fundamental element in scientific research and, in this study, we were concerned with the validation of several constructs – i.e. the lean leadership competencies. Three validation types were encompassed: face validity, content validity, and predictive

No.	Authors	Is leadership the main subject? (yes/no)	Research approach	Focus	Sector	Main contribution
1	Achanga *et al.* (2006)	No	Case study	Leadership as a critical factor	Manufacturing	The critical factors for LPS implementation are identified and leadership is among them
2	Bhasin (2012)	No	Survey and case studies	Leadership as a critical factor	Manufacturing	It explores the design of a strategy for implementing LPS and the importance of leadership
3	Found and Harvey (2007)	Yes	Theoretical	Roles and responsibilities of lean leaders	Manufacturing	It discusses whether leadership style influences a lean implementation. It also discusses the change in leadership role during an implementation
4	Holmemo and Ingvaldsen (2015)	Yes	Case study	Leadership as a critical factor	Services	Through five case studies, the article discusses the lack of middle managers' involvement in LPS implementation
5	Al-Najem *et al.* (2012)	Partially	Theoretical	Leadership as a critical factor	Not specified	It studies the importance of leadership in an LPS implementation from a framework of culture lean assessment
6	Hartwell and Roth (2010)	Yes	Case study	Leadership as a critical factor	Manufacturing	The article presents a case sudy of an LPS implementation and discusses the role of leadership in it
7	Liker and Ballé (2013)	Yes	Case study	Roles and responsibilities	Manufacturing	It presents the role of leadership for people development. Based on the authors' own experience in Toyota
8	Mann (2009)	Yes	Theoretical	Leadership as a critical factor	Not specified	It proposes a leadership framework that covers all hierarchical levels in an organization
9	Ballé, Bouthillon (2011)	Yes	Case study	Roles and responsibilities	Construction	The article discusses, from a case study, the role of leadership in a lean construction implementation
10	Goodridge *et al.* (2015)	Yes	Case study	Roles and responsibilities	Healthcare	It proposes a list of leadership practices from data collected in interviews, workshops and document reviews
11	Alagaraja and Egan (2013)	Partially	Theoretical	Leadership as a critical factor	Manufacturing	It proposes a framework of people development where leadership is one of the three categories of analysis

(*continued*)

Table I.
Overview of leadership literature in LPS

No.	Authors	Is leadership the main subject? (yes/no)	Research approach	Focus	Sector	Main contribution
12	Emiliani (2003)	Yes	Theoretical	Behaviors and competencies	Not specified	It presents a list of leadership competencies required in an LPS implementation
13	Emiliani and Stec (2004)	Yes	Theoretical	Leadership development	Manufacturing	It proposes the use of value stream mapping (VSM) for identification of leaders' improvements
14	Emiliani and Stec (2005)	Yes	Case study	Leadership as a critical factor	Not specified	It discusses leaders' failures in LPS implementation
15	Marodin and Saurin (2015a)	No	Survey	Leadership as a critical factor	Manufacturing	Leadership is cited as a factor to reduce the impact of various barriers on LPS implementation
16	Alagaraja (2014)	Partially	Theoretical	Leadership as a critical factor	Not specified	It discusses the importance of people's development. The article identifies leadership as a facilitating factor for an implementation
17	Wyton and Payne (2014)	No	Case study	Leadership as a critical factor	Manufacturing	The article presents, from a case study, the learning improvements about LPS with an action learning approach
18	Poksinska, Swartling and Drotz (2013)	Yes	Case study	Roles and responsibilities	Manufacturing and healthcare	It discusses the changes in the leaders' daily routine in an LPS implementation
19	Liker and Convis (2012)	Yes	Theoretical/ Case study	Leadership development	Manufacturing	It presents a framework for leadership development and a case
20	Liker and Trachilis (2014)	Yes	Theoretical	Leadership development	Manufacturing	It presents a framework for leadership development and a case
21	Emiliani (1998)	Yes	Theoretical	Behaviors and competencies	Manufacturing	The article develops the concept of lean behavior as an important element to be considered in an LPS implementation
22	Spear (2004)	Yes	Case study	Leadership development	Manufacturing	It describes the development of a new manager in Toyota

Table I.

validity (Table II). According to Trochim *et al.* (2015), face validity refers to the analysis of whether the definition of the construct looks good, and it is essentially subjective, usually relying on expert's assessment. Content validity checks the construct against the relevant content domain, assuming that the content domain is well detailed (Trochim *et al.*, 2015). As to predictive validity, it assesses the construct's ability to predict something it should theoretically be able to predict (Trochim *et al.*, 2015).

Research steps	Validation steps	Type of validity	Criteria
(1) A literature review to develop a list of competencies and their descriptions	Competencies identified in the literature	Content validity	Criteria for literature review and identification of competencies
(2) Refinement of the lean leadership competencies descriptions with experts	Competencies relevance and writing	Face validity	Interviews with LPS experts
(3) Verification of the level of agreement of lean leadership competencies with core lean principles	Conceptual-theoretical	Content validity	Adherency to the LPS principles
(4) Empirical validation of the lean leadership competencies	Survey instrument	Content validity	Pre-test with scholar and professionals
	Empirical	Predictive validity	Correlation with experience time with LPS (leader) Correlation with academic background (leader) Coorrelation with professional experience time (leader) Correlation with maturity level of the LPS (organization) Corrrelation with performance indicators in the area where LPS was implemented (organization) Correlation with experience time with LPS (organization)

Table II.
Overview of the validation types used in the study

3.2 Literature review to develop a list of competencies and their descriptions

The search for papers that could contribute to competencies identification was based on the literature identified in a database search using the terms "lean" and "competencies" on July 30, 2015. The following databases were used: Scopus, Emerald Journals, Sage Journals, Springer Link, IEEE Journals, Willey on line Library, and Web of Science. The search was restricted to papers in English, without being restricted to any publication date. A total of 58 articles were identified, and those whose main subject was not "lean" were ruled out. This narrowed down the selection to 18 articles. These papers were entirely read, and the ones not contributing for the identification of competencies were eliminated. At the end of this process, 11 papers were left.

In these 11 papers, an analysis was made to spot excerpts of text that pointed out examples of leaders' actions and intentions that contributed to implementing lean principles. The emphasis on actions and intentions was due to the previously mentioned definition of competency proposed by Boyatzsis (2008).

For instance, the following excerpt was extracted from Liker and Hoseus (2009): "[…] problems identified are solved by getting a cross-functional and cross-level team together and allowing them to use the problem-solving process and empowering them to make the decisions necessary to take care of the problems."

Based on this excerpt, we inferred that a leadership competency could be stated as "identify and solve problems with the teams using the PDCA principle." The excerpt was associated with an action (i.e. "an empowered team solving a problem using problem-solving process"), and an intention (i.e. "to develop people"). As a result of this process, 19 lean leadership competencies were identified.

The competencies were described as pragmatically and objectively as possible, so as they could make sense and resound with practitioners. In fact, descriptions of competencies in generic and ambiguous ways are often presented as a criticism to existing competency models (Teodorescu and Binder, 2004).

3.3 Refinement of the lean leadership competencies descriptions with experts

The preliminary list of competencies was discussed and refined with four lean experts, comprising two consultants and two scholars, which provided balanced practical and theoretical perspectives.

Two questions were asked for each competency in order to refine the list with the experts: whether the competency was relevant for a lean leadership, and whether the competency was clearly described. Experts were invited to point out reasons and suggestions for addressing any disagreements they had in relation to the list. This process narrowed down the number of competencies from 19 to 16.

3.4 Verification of the level of agreement of lean leadership competencies with core lean principles

The 16 identified leadership competencies were analyzed in light of the lean principles proposed by Liker (2004). The analysis checked for conceptual consistency between the description of the principles and the statement of the competencies.

3.5 Empirical validation of the lean leadership competencies

3.5.1 Survey. A questionnaire containing 97 questions was designed and sent to the respondents, who were asked to identify a lean implementation they were acquainted with. Respondents should assess both implementation and leadership, considering that the leaders could be themselves. The survey questionnaire was divided into four sections:

(1) Characterization of the analyzed leader: questions were asked about the leader's profile (hierarchical position, experience in LPS, educational and professional background) as well as their level of leadership competency development. Each respondent assessed the development level of each competency ranking from 1 (little developed) to 5 (very developed).

(2) Characterization of the analyzed system in which LPS was implemented: the system could be a cell, an assembly line, a department, or a whole plant. The questions about the analyzed system aimed to assess the performance level of its indicators over the last three years. In order to assess it, a scale from 1 (worsened a lot) to 7 (improved a lot) was suggested, with 4 the indicator of unaltered performance. In total, 11 performance indicators were selected based on proposals by Shah and Ward (2003) and Rahman *et al.* (2010), in addition to three others related to Human Resource Management: safety, absenteeism, and turnover.

(3) Characterization of the company: questions were asked about the presence of a formal LPS project, LPS maturity level in the company, company sector, among others. Based on Hallam and Keating (2014), the maturity level could be assessed in a 5 level range, from 1 (little knowledge of lean; ongoing random improvement activities in some areas) to 5 (exceptional, well defined and innovative approach; it is applied across the supply chain; acknowledged as the best practice).

(4) Characterization of the respondent: this was useful to identify the respondent's relationship with the analyzed leadership, in case the assessment had not been about him or her. Questions were also asked about the respondent's experience and level of knowledge in LPS.

A pre-test with two scholars and two practitioners was done in order to test the questionnaire, its questions writings, and scales. Their feedback and suggestions were included in the version of the questionnaire that was sent to potential respondents.

3.5.2 Sample. The main criterion for selecting the respondents was that these had either personal experience conducting an LPS implementation in the previous 12 months or followed it up closely enough in order to assess a leader's performance in this process.

An electronic invitation to take part in the research was sent to 15,200 contacts of an LPS executive training database of the most important research universities in the South of Brazil, which included mostly professionals from companies in general, but also students, professors, and consultants. Among these contacts, 145 people responded positively both in terms of selection criterion and availability to participate.

The final sample consisted of 91 valid answers (63 percent). In brief, it is possible to characterize the respondents' group profile as academically qualified (all of them have a college degree and 32 percent are post-graduated), professionally experienced (54 percent with more than 15 years' experience), and acquainted with the lean theory and practice (72 percent with more than four years of experience in LPS, and 40 percent considered themselves experts in LPS).

Concerning the profiles of the leaders evaluated by respondents, despite being distributed across several hierarchical levels, they are predominantly made up of professionals who hold managerial positions (60 percent). The leaders have a college degree (98 percent), and most of them attended post-graduation courses (65 percent). These are also professionals with a fairly good professional experience and with LPS as well (48 percent with more than five years of experience).

In terms of the assessed companies, they are, in general, large-sized companies (73 percent with more than 250 employees), focused on manufacturing (78 percent), formally involved in lean projects for at least three years (76 percent), stand in intermediate maturity level of development of lean (42 percent), and have performance indicators related to the topic (68 percent). Most of the companies used consultancy support (58 percent) in their LPS implementation. Table AI presents a summary of the respondents' and leaders' profiles, as well as a more detailed characterization of the assessed companies.

3.5.3 Data analysis of the survey. To empirically test the predictive validity of the lean leadership competencies, we relied into an individual and an organizational perspective. First, we assumed that leaders that have a high degree of those competencies would also have more knowledge and experience with LPS. More time spent in training and acquiring formal knowledge about LPS and also active participation in implementing lean practices would help to develop those competencies.

Second, the fact that the leader is embedded into a working environment that has a more mature LPS implementation would expose them to develop their leadership competencies. Managers get more, not less, committed to and involved in the lean implementation in high maturity plants (Netland, 2016). Thus, we proposed to test the two hypotheses as follows:

H1. Lean leadership competencies are positively associated with leader's maturity level in LPS.

H2. Lean leadership competencies are positively associated with organizational maturity level of LPS.

Three criteria were defined to measure the organizational maturity level of LPS implementation, namely, degree of LPS implementation, operational performance, and company's experience time with LPS. In turn, other three criteria measured the leader's maturity level in LPS: leader's experience time with LPS, leader's academic background, and leader's professional experience time. We carried out the data analysis in two steps.

First, a principal component analysis (PCA) was conducted, with Varimax orthogonal rotation, in order to reduce the effects of correlations between variables (i.e. lean leadership competencies) as well as to obtain one underlying construct that represented the overall degree of the lean leadership competencies.

Second, we used Pearson bi-variate correlations (Pearson's r) to test the association between variables and validate the proposed hypothesis. When appropriate, the bi-variate correlations were conducted with all variables, as well as with the reduced construct that emerged from the PCA. This procedure was used when testing the association between lean leadership competencies and operational performance metrics because the latter have multiple items that were used to measure, instead of only one (e.g. LPS maturity level).

3.5.4 Review of the survey data with respondents. The results of the survey were presented in a feedback meeting with a group of respondents from the survey. An invitation was sent to the 91 original respondents and 6 of them accepted it. The meeting lasted 4 hours, and it was audio recorded and transcribed. The researcher presented the results for each of the four sections of the questionnaire, emphasizing findings related to the two hypotheses. As suggested by Voss *et al.* (2002), participants were asked to offer their views on the findings, especially in terms of their accuracy and possible interpretations. Furthermore, practical implications of the results were pointed out by respondents.

4. Results and discussions

4.1 Proposed list of lean leadership competencies

The results of the first three steps described in the research method are presented in this section. Table III shows the list of the 16 competencies that emerged from the literature review and were refined by experts, as well as their association with the 14 lean principles proposed by Liker (2004).

The studies by Liker and Hoseus (2009), and Emiliani and Stec (2004) were the ones that contributed the most with 14 and 15 competencies, respectively. The competencies were explicitly presented in only two articles (Emiliani, 2003; Emiliani and Stec, 2004), although the methods for their identification have not been detailed. In other studies, the terms skills, attributes (Hilton and Sohal, 2012), or factors that influence lean implementation (Alagaraja, 2014; Nordin *et al.*, 2012) were used. For example, Alagaraja (2014) identified the top management's short-term view as well as the lack of communication skills as factors that hinder LPS implementation. Such factors have been reinterpreted as leadership competencies.

Based on Table III, competencies were considered to be associated with, at least, four principles, and, at most with all of them (i.e. 14). On the one hand, C11 was associated with only four principles. This can be due to the personal continuous evolution included in the scope of C11, which values individual traits in addition to the organizational characteristics emphasized by the lean principles. On the other hand, the competencies associated with all principles were C1, C3, and C13. These competencies can have a higher degree of importance than others, assuming that the analyzed associations correspond to a proxy measure of importance.

Table III also indicates that some competencies were relatively much more associated with the principles than mentioned in the reviewed literature – i.e. C7 and C14. This suggests that the importance of these competencies has been underestimated by many studies, which can result from the low development of the competencies in real settings. In turn, C9 and C11 are relatively much more stressed by the literature than associated with the principles. This may be due to the aforementioned interpretation regarding C11, which also applies to C9. Both competencies seem to be significantly related to individual traits, which are not emphasized by the lean principles. This indicates an opportunity to develop the lean theory further.

	Lean leadership competencies	References used in the literature review	Agreement with references used (% of total number of references)	Lean principles	Agreement with lean principles (% of total number of principles)
C1	Identify what adds value to internal and external clients	a, b, c, d, e, f, g, h, i, k	91	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	100
C2	Identify and solve problems with their teams using the PDCA principle (coaching)	a, b, d, e, g, i, j, k	73	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14	93
C3	Use continuously lean practices and principles	a, b, c, d, e, f, g, k	73	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	100
C4	Manage with emphasis on value flow rather than on isolated operations	a, b, c, d, e, h, j, k	73	2, 3, 4, 5, 9, 11, 13, 14	50
C5	See the problems with your own eyes (based on data and facts)	a, b, d, e, g, h, i, k	73	2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14	86
C6	Lead through example	a, b, c, d, e, g, h, i, k	82	5, 7, 9, 10, 12, 13, 19	50
C7	Stabilize processes	a, b, e, h	36	2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14	93
C8	Provide value-added information clearly and objectively	a, b, c, d, e, h, j, k	73	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 13, 14	86
C9	Put the group's interests above the individual ones	a, b, c, d, e, g, i, j, k	82	5, 8, 9, 10, 13	36
C10	Develop and implement guidelines, plans and policies aiming at people's development	c, d, e, g, i	45	5, 9, 10, 13, 14	36
C11	Practice self-development as well as professional and personal continuous evolution	a, b, c, d, g, i, k	64	5, 9, 12, 13	29
C12	Identify and manage barriers during lean production journey	c, d, e, f	36	1, 5, 6, 7, 8, 9, 10, 11, 13, 14	71
C13	Practice lean as an interrelated system of principles and practices	c, d, e, g, g, h, k	64	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	100
C14	Develop actions based on long-term views	a, c, e, f, i	45	1, 2, 4, 5, 6, 9, 10, 11, 13, 14	71
C15	Develop actions that, based on ethical principles, respect the community, the environment and the workers' safety	a, d, e, f, g, j	55	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14	93
C16	Develop innovative and challenging actions	b, c, d, e, f, g, i, j, k	82	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14	93

Notes: References: a – Emiliani (2003); b – Hilton and Sohal (2012); c – Alagaraja (2014); d – Liker and Hoseus (2009); e – Emiliani and Stec (2004); f – Emiliani and Stec (2005); g – Spear (2004); h – Found *et al.* (2009); i – Dombrowski and Mielke (2014); j – Poksinska *et al.* (2013); k – Wyton and Payne (2014); lean principles (Liker, 2004): 1 – base your management decisions on a long-term philosophy, even at the expense of short-term financial goals; 2 – create continuous flow to bring problems to the surface; 3 – use pull systems to avoid overproduction; 4 –level out the workload (Heijunka); 5 – build a culture of stopping to fix problems, to get quality right first time; 6 – standardized task are the foundation for continuous improvement and employee empowerment; 7 – use visual control so no problems are hidden; 8 – use only reliable, thoroughly tested technology that serves your people and process; 9 – grow leaders who thoroughly understand the work, live the philosophy and teach it to others; 10 – develop exceptional people and teams, who follow your company's philosophy; 11 – respect your extended network of partners and suppliers by challenging them and helping them to improve; 12 – go and see for yourself to thoroughly understand the situation (Genchi genbutsu); 13 – make decisions slowly by consensus and thoroughly considering all options, implement decisions rapidly (Nemawashi); 14 – become a learning organization through relentless reflection (Hansei) and continuous improvement (Kaizen)

Table III.
Leadership competencies and association with lean principles

Although the lean theory is well known for emphasizing the role of the context on people's behavior (e.g. rather than emphasizing who made a mistake, lean is concerned with the role played by systems), it seems that the mainstream lean theory has not paid sufficient attention to the individuals' personality traits and unique personal qualifications.

4.2 Empirical validation of the lean leadership competencies

4.2.1 Leader's maturity level in LPS and lean leadership competencies. The first test was the association between leader's experience time with LPS and the first principal component of competency development, which represents 46 percent of the variance of the construct. The correlation was positive and significant of 0.510 (p-value = 0.000). Indeed, if the leader's competencies develop as their experience with LPS increases, this is in line with the leadership development practice through coaching and mentoring by Toyota. In Toyota, the coach is always someone with wide experience in the system and considered to have advanced leadership competencies (Spear, 2004). Furthermore, a continuous improvement environment could be a contributing factor to this result, since the more experienced the leader, the more exposed they will be to problem solving using the scientific method.

The second test was the association between leader's formal academic level and lean leadership competencies. The majority of the assessed leaders have a graduate degree (65 percent), and almost all of them also have a college degree (98 percent). Pearson's r between the first principal component of competency development and the leader's academic background was 0.251, being positive and significant (p-value = 0.009). Formal education is well known for developing logic reasoning, abstract, and critical thinking (Ernst and Monroe, 2004), which are assets for all lean competencies.

The third test was the positive (Pearson's $r = 0.208$) and significant association (p-value = 0.035) between leader's professional experience and lean leadership competencies. The assessed leaders are experienced professionals, having an average of 14.4 years of experience, and 68 percent with more than 10 years of experience.

The association of competency development with the leader's experience time with LPS, adding to their academic background and professional experience, points to the importance of leaders and companies' Human Resources (HR) in planning leadership development. Alagaraja and Egan (2013) discuss the assessment of training needs, skill evaluation, and systematic leadership development as examples of initiatives from HR staff to support LPS efforts.

In sum, all the three variables that were used to test *H1* were significantly positive. Thus, we concluded that the developed list of lean leadership competencies is positively associated with leader's maturity level in LPS, and *H1* cannot be rejected.

4.2.2 Organizational maturity level of LPS and lean leadership competencies. The first variable that was used to test the association of organizational maturity level of LPS and lean leadership competencies was the degree of LPS implementation. The correlation between lean leadership competencies and degree of LPS implementation in the company was positive and significant at 0.257 (p-value = 0.006).

The second variable that was used to test the association of organizational maturity level of LPS and lean leadership competencies was the operational performance. Pearson's r between each competency and each indicator was calculated, which generated a matrix of correlations (Table IV). The analysis of the matrix indicates that:

(1) All competencies have significant correlations with at least one indicator, which suggests that the efforts to develop competencies can result in tangible benefits associated with operational indicators.

(2) All significant correlations are positive, indicating that efforts to develop all competencies, rather than only some of them, are recommended.

	WP	EE	IT	OTD	CS	QFT	WS	LT	SR	AB	TO
C1	Non-signif.	Non-signif.	Non-signif.	0.273 (0.004)[a]	0.260 (0.006)	0.215 (0.020)	0.279 (0.004)	0.229 (0.015)	0.206 (0.025)	Non-signif.	Non-signif.
C2	Non-signif.	0.198 (0.030)	Non-signif.	Non-signif.	0.174 (0.050)	0.198 (0.030)	0.323 (0.001)	Non-signif.	Non-signif.	Non-signif.	Non-signif.
C3	0.299 (0.002)	Non-signif.	Non-signif.	0.196 (0.031)	Non-signif.	0.262 (0.006)	0.228 (0.015)	0.211 (0.022)	0.174 (0.050)	Non-signif.	Non-signif.
C4	0.289 (0.003)	Non-signif.	Non-signif.	0.317 (0.001)	Non-signif.	Non-signif.	0.180 (0.044)	Non-signif.	Non-signif.	Non-signif.	Non-signif.
C5	Non-signif.	0.205 (0.026)	Non-signif.	Non-signif.	Non-signif.	Non-signif.	Non-signif.	Non-signif.	Non-signif.	Non-signif.	Non-signif.
C6	Non-signif.	Non-signif.	Non-signif.	Non-signif.	Non-signif.	0.184 (0.040)	0.288 (0.003)	Non-signif.	Non-signif.	Non-signif.	Non-signif.
C7	0.223 (0.017)	Non-signif.	Non-signif.	0.238 (0.011)	0.258 (0.007)	0.350 (0.000)	0.357 (0.000)	Non-signif.	0.191 (0.035)	Non-signif.	0.187 (0.038)
C8	Non-signif.	Non-signif.	Non-signif.	Non-signif.	Non-signif.	0.199 (0.029)	Non-signif.	Non-signif.	Non-signif.	Non-signif.	Non-signif.
C9	Non-signif.	Non-signif.	Non-signif.	Non-signif.	Non-signif.	Non-signif.	0.203 (0.027)	Non-signif.	Non-signif.	Non-signif.	Non-signif.
C10	Non-signif.	0.187 (0.038)	Non-signif.	0.234 (0.018)	0.203 (0.027)	0.253 (0.008)	0.372 (0.000)	Non-signif.	Non-signif.	Non-signif.	Non-signif.
C11	Non-signif.	0.251 (0.008)	Non-signif.	0.272 (0.005)	0.189 (0.036)	Non-signif.	0.184 (0.040)	Non-signif.	Non-signif.	Non-signif.	Non-signif.
C12	Non-signif.	Non-signif.	Non-signif.	Non-signif.	0.185 (0.040)	0.259 (0.007)	0.185 (0.040)	Non-signif.	0.191 (0.035)	Non-signif.	Non-signif.
C13	0.33 (0.001)	Non-signif.	Non-signif.	0.281 (0.030)	0.175 (0.049)	0.293 (0.002)	0.203 (0.027)	0.212 (0.022)	0.212 (0.022)	Non-signif.	Non-signif.
C14	Non-signif.	Non-signif.	Non-signif.	0.174 (0.050)	0.179 (0.045)	0.213 (0.021)	0.203 (0.027)	0.214 (0.021)	Non-signif.	Non-signif.	Non-signif.
C15	Non-signif.	Non-signif.	Non-signif.	Non-signif.	Non-signif.	Non-signif.	0.260 (0.006)	Non-signif.	Non-signif.	Non-signif.	0.184 (0.040)
C16	0.254 (0.008)	0.189 (0.036)	Non-signif.	Non-signif.	0.236 (0.012)	0.242 (0.010)	Non-signif.	Non-signif.	Non-signif.	Non-signif.	Non-signif.

Notes: [a]Number in parenthesis is the *p*-value; WP, workforce productivity; EE, equipment efficiency; IT, Inventory Turns; OTD, on-time-delivery; CS, customer satisfaction; QFT, quality right at the first time; WS, work safety; LT, lead time; SR, scrap and rework; AB, absenteeism; TO, turnover

Table IV.
Matrix of correlations between competency development and performance indicators

(3) Leaders should be encouraged to develop improvements in safety (SA), and quality (QFT) issues due to the high number of significant correlations (13 and 11, respectively) between the competencies and the safety and quality indicators. In the previously mentioned feedback meeting, participants reported that these results made sense, since improvements in safety and quality require teamwork at the front line and a high level of social interaction between leaders and followers in order to change behaviors.

(4) Absenteeism (AB) and inventory turns (IT) indicators did not have significant correlations with any competency, while turnover (TO) indicator with only one competency. These metrics are likely to be strongly influenced by other factors. For instance, concerning IT, the characteristics of the company's market demands or the type of product could have exerted strong influence as well as the company' position in the supply chain. This interpretation was highlighted by the group of participants of the feedback meeting. Furthermore, these findings are in line with the conclusions of a recent empirical survey in a similar sample of Brazilian companies (Marodin *et al.*, 2016), which found that IT and TO metrics did not have significant improvement as a result of lean implementation.

(5) Indicators that have no significant correlations with the competencies could be dependent on technical variables to a larger extent. For example, lead time indicator, which is impacted by four competencies (C1, C3, C13, C14), might be more dependent on technical variables (e.g. process and machine specifications) than on social variables (e.g. team interactions).

The association between lean leadership competencies and operational performance indicators was also performed using a reduced number of variables of performance metrics. The PCA was conducted to find the underlying constructs for the 11 performance metrics, and the first component extracted contains 34 percent of the total variance of the construct. Pearson's r was calculated between the first principal component of competency development and the first principal component of the performance indicators. A significant correlation equal to 0.346 (p-value = 0.004) was found.

The third variable that was used to test the association of organizational maturity level of LPS, and lean leadership competencies was the company's time experience with LPS. There was no significant correlation between the first principal component of leadership competencies and the company experience time with LPS. This result can be related to the difficulties the companies involved in this study have to sustain LPS initiatives and outcomes over time this interpretation is in line with earlier studies (Bhasin, 2012; Hines *et al.*, 2011).

Another possible interpretation is to relate these results to high leaders' turnover as well as to the lack of formal mechanisms of transfer and record of tacit knowledge. This turnover can result from the influence of external contextual factors, such as the lack of specialized workforce. In fact, one of the questions was about the availability of specialized workforce and the result was found in the middle of the scale (2.0) from 1 (low availability) to 3 (high availability).

In fact, companies that seek to implement LPS may be recruiting managers from other companies. This was the case of two of the participants in the feedback meeting, who had been working at their present companies for less than two years, even though they had a previous longer experience with lean in other companies. Moreover, 51 percent of the assessed leaders had less than three years of experience with LPS. In sum, two of the three variables that were used to test *H2* were significantly positive. Thus, we concluded that the developed list of lean leadership competencies is positively associated with the organizational maturity level of LPS, and thus *H2* cannot be rejected. Figure 1 presents a summary of the hypotheses tested for the empirical validation.

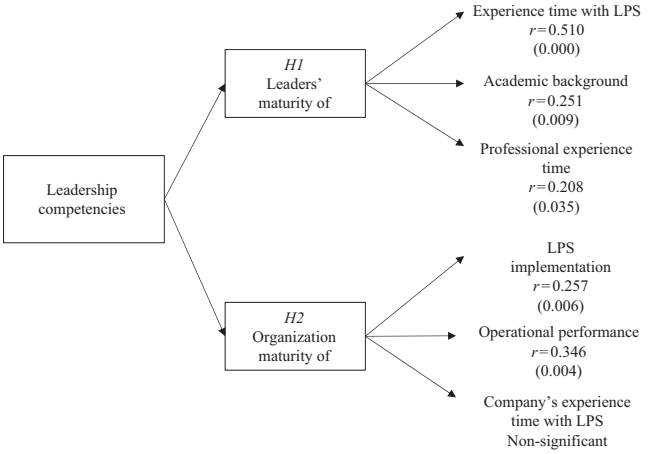

Figure 1.
Summary of hyphotheses tested

5. Conclusions

5.1 Contributions of this study

The research question addressed in this study was stated as follows:

RQ1. What are the leadership competencies required to support an LPS implementation?

Thus, a list of 16 competencies was developed based on a verifiable research method that used a mix of data collection techniques, which provided both theoretical and empirical support. This is a distinctive characteristic in comparison with earlier studies of LPS leadership.

The findings indicate the validity of the 16 identified competencies, based on a multi-method approach. Furthermore, an important result from the empirical research is related to the positive and significant correlations between lean leadership competencies and leader's maturity level in LPS as well as the organizational maturity level of LPS.

The empirical findings of this study, which suggest a positive correlation between the development of competencies and operational performance, should be interpreted as encouragement for managers when making decisions about whether to invest in developing competencies for LPS implementation. This study offered insights into the understanding of the sustainability of an LPS, indicating that leadership competencies play an important role in the maturity of an LPS and its performance. Furthermore, the identified list of lean leadership competencies identified sets a basis for designing formal leadership development programs as well as to the development of tools to assess and manage them.

5.2 Limitations

Some limitations of this research study should also be noted. First, the survey did not account for some contextual variables, such as competitiveness, macro-economic scenario, and position of the company in the supply chain, among others. Second, the characteristics of the sample itself limit generalizations, both in terms of the companies and leaders assessed. Third, different terms and criteria for searching the studies in the literature review could have resulted in a different selection of studies.

5.3 Future studies

Some opportunities for further research can be stressed, such as: the investigation of the impacts of competency development in other samples of companies and leaders; analyses of

the competencies development in different hierarchical levels in the organization and in companies with different lean maturity levels; analyses of how leaders' social (e.g. communication) and technical skills affect the competencies; the investigation of the necessary competencies in variants of the lean system, such as Lean Six Sigma and Lean Agile; and refinement of the identified list of competencies, by checking it against general leadership theories, which have been pointed out as relevant for lean leadership (e.g. transformational leadership, and servant leadership).

Lastly, it is worth noting that other methodologies could be used to identify the competencies of lean leaders and their correlations with different aspects of an LPS. In particular, we suggest the use of systems' thinking approaches (e.g. system dynamics models), since these can shed light on the relationships between the competencies themselves and between these and a broad range of contextual factors.

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Appendix

Leadership		Respondents		Companies	
Hierarchy level		*Academic background*		*Presence of a formal LPS project*	
Managers	60%	Undergraduation	37%	Yes	76%
Top management	11%	Graduation	60%	No	24%
Consultants	11%	High school	3%	*Project duration (in years)*	
Team leaders, process engineers	18%	*Experience time with LPS*		Up to 5 years	75%
Academic background		Less than 3 years	14%	More than 5 years	25%
Undergraduation	66%	Between 3 and 5 years	25%	Average (years)	4.9
Graduation	32%	Between 6 and 9 years	25%	*LPS maturity level*	
High school	2%	10 years or more	35%	Beginner	42%
Experience time with LPS		Average (years)	8.0	Intermediate	42%
Less than 3 years	29%	*Professional experience time*		Advanced	16%
Between 3 and 5 years	21%	5 years or less	15%	*Competitiveness*	
Between 6 and 9 years	16%	Between 6 and 10 years	20%	Very high	35%
10 years or more	33%	10 years or more	65%	High	34%
Average (years)	6.7	Average (years)	16.6	Intermediate	22%
Professional experience time		*Level of expertise in LPS*		Low	5%
5 years or less	14%	Beginner	11%	Very low	3%
Between 6 and 10 years	18%	Intermediate	45%	*Workforce availability*	
10 years or more	68%	Advanced/Expert	44%	Low	19%
Average (years)	14.4	*Has evaluated him/herself as the leader?*		Neither low nor high	62%
		Yes	48%	High	20%
		No	52%	*Type*	
				Manufacturing	78%
				Processes	11%
				Services	11%
				Variety and volume of products and services	
				Low volume and low variety	7%
				High volume and low variety	20%
				Low volume and high variety	25%
				High volume and high variety	48%
				Company size	
				Small (1-49 employees)	4%
				Medium (50-249 employees)	23%
				Large (more than 250 employees)	73%
				Workforce education	
				Middle school	20%
				High school	75%
				College degree	5%
				Presence of indicators in line with LPS principles	
				No presence	9%
				Present, but partially aligned	68%

(*continued*)

Table AI. Profile of respondents, leaders and companies assessed

Leadership	Respondents	Companies	
		Present and completely aligned	23%
		Reason for LPS implementation	
		Company's own initiative	62%
		Headquarters' initiative	19%
		Clients' demands	19%
		Ways of LPS development	
		With internal personnel	33%
		With headquarters' personnel	8%
		With client's support	1%
		With external consulting support	58%

Table AI.

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