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On the application of Lean principles and practices to innovation management

A systematic review

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Abstract
Purpose – Increasingly, a firm's innovation capability has become one of the key frontiers of competitive advantage. The Lean philosophy has a well-proven reputation for its focus on process efficiency and effectiveness, and therefore, is often applied in various areas of innovation. Such wide and ever-increasing applicability also has resulted in an incoherent corpus of literature on Lean innovation. The purpose of this paper is to conceptualize an integrative view on Lean innovation management.
Design/methodology/approach – Based on a systematic literature review, the key Lean principles and practices useful in the context of innovation management are identified and synthesized into an all-inclusive framework. By means of three illustrative cases (i.e. public hospital, electronics company and avionics manufacturer), this paper elaborates on how the proposed framework can be applied.
Findings – A total of 88 publications are analyzed, leading to 34 Lean principles and practices relevant to innovation management, which are further integrated into a comprehensive model, dubbed the "Leanovation" framework.
Originality/value – This study is the first attempt to advance the understanding of various interrelated and interdependent components of Lean innovation management in a holistic way.

Keywords Lean philosophy, Toyota Production System, Innovation management, Leanovation framework, Systematic literature review
Paper type Research paper

1. Introduction

Innovation drives our economic prosperity and is vital for firms' profitability, growth and competitive advantage (Denton, 1999; Porter, 1990; Tidd *et al.*, 2005). It is part of almost every conceivable aspect of business, from products and services to processes and technologies to business and cost-revenue models. Yet disorder and unpredictability, sometimes termed "chaos," seem to epitomize the prevailing perception of the innovation process (Guston, 2008). To arrive at what Quinn (1985) describes as "controlled chaos," scholars increasingly earmark "innovation management" as the way to successfully spur innovation (Trott, 2008). The key underlying idea is that only through efficient and effective management of innovation, firms can stimulate and absorb novel ideas and navigate them toward valorization and full-fledged commercialization (Tidd *et al.*, 2005).

As one of the most prominent innovations in the field of production and operations management, the Lean philosophy provides principles and practices to rejuvenate innovation capability. After all, Toyota, frequently credited as the pioneer of Lean philosophy, has been

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one of the most consistent innovators alongside Apple, Google and Microsoft (Ringel *et al.*, 2015), producing a multitude of incremental and disruptive innovations represented by highest numbers of patents in the automotive industry (Pohl, 2012; Thomson Reuters, 2015; Tan and Perrons, 2009). The Lean philosophy focuses on adding value for stakeholders, particularly customers, and encouraging employee's continuous contribution to safety, quality and performance improvements, while maintaining a holistic focus on the end-to-end process. However, although the complementary relationship between Lean and innovation is broadly recognized (Browning and Sanders, 2012; Schuh, 2013; Sehested and Sonnenberg, 2011), the increasing body of knowledge on the application of Lean to innovation management remains scattered and unstructured, with remarkable diversity of concepts such as knowledge transfer (Lindlöf *et al.*, 2013), new product development (NPD) (Anand and Kodali, 2008; Biazzo *et al.*, 2016), design engineering (Baines *et al.*, 2006), concurrent engineering (Karlsson and Åhlström, 1996; Al-Ashaab *et al.*, 2013), value system (Siyam *et al.*, 2015) and continuous improvement (Salah, 2017).

This study aim to address the question of "how Lean principles and practices are applied to innovation management?" To develop a holistic understanding of Lean innovation management, in this paper a systematic review of literature on "Lean within innovation management" setting is conducted. By doing so, this paper aims to synthesize innovation-specific Lean principles and practices into an integrative model. Such model aims to help scholars and practitioners to establish a more efficient and effective "system" to manage innovation processes, instead of being limited to the "scattered" or "siloed" parts of such system.

The paper is structured as follows. To set the wider context, Section 2 elaborates on the Lean philosophy after which Section 3 outlines the research method. The findings are discussed in Section 4, where the literature is synthesized into a holistic view on Lean innovation management (named the Leanovation framework). Section 5 describes the relationship between various dimensions of the Leanovation framework. The paper concludes with a discussion of theoretical and managerial implications, provides several illustrative examples and suggests potential areas for future research.

2. Lean in innovation management context

In their seminal book summarizing the findings of an international benchmarking study of car assembly plants, Womack *et al.* (1990) brought the famed Toyota Production System (TPS) to a wider audience and described the principles and practices that helped the firm achieve its superior performance. They popularized the term Lean to refer to a compendium of manufacturing, NPD and supplier relations practices. Ever since, Lean has been one of the most salient and widely cited concepts in the operations management literature (Holweg, 2007). Although definitions of Lean production or manufacturing are in abundance (for a systematic overview, see Shah and Ward, 2007, p. 788; Pettersen, 2009, p. 130), in a more generic view, continuous improvement, waste elimination and variability reduction have been the traditional focus of Lean production (e.g. Hines *et al.*, 2004; Hopp and Spearman, 2004).

Since its introduction, opinions and interpretations of Lean's essence and its application have been increasingly diverse and continuously evolved (Hoss and ten Caten, 2013; Ruffa, 2008), so much so that Bhasin and Burcher (2006) propose to refer to Lean as a "philosophy" or way of thinking facilitated with practices for both "soft" social and cultural aspects and "hard" tools or processes. Most striking is the antithesis between the traditional interpretation of Lean and the contemporary school of thought (Bozdogan, 2010). In this respect, the generally accepted practices from the TPS epoch seem to have made room for a more liberal interpretation of the Lean philosophy that tends to contextualize – and consequently reprioritize the relevance of – various TPS principles and practices. Within this interpretation, three patterns in the evolution of Lean philosophy are noteworthy.

First, although the concept has its genesis in the automotive industry, a wide variety of industries have benefited from or studied the benefits of the Lean philosophy, e.g., government (Radnor, 2010), healthcare (Ferreira *et al.*, 2018), construction (Green and May, 2005; Forbes and Ahmed, 2010), textiles and clothing (Bruce *et al.*, 2004), aerospace (Crute *et al.*, 2003), food (Jie and Gengatharen, 2019), software development (Poppendieck and Poppendieck, 2003), mining (Kippel *et al.*, 2008), service industries (George and George, 2003; Swank, 2003) and universities (Hines and Lethbridge, 2008).

Second, the Lean philosophy has been integrated using various theoretical concepts, and hence the Lean frame of reference has been extended. For example, Lean philosophy has been reappraised to cope with a volatile marketplace and changing customer demands by combining it with agility to form Leagility (e.g. Naylor *et al.*, 1999), which promotes a Lean approach "upstream" of the process to enable a level schedule and drive down costs, while ensuring an agile response "downstream" by creating the capability of delivering in unpredictable markets (cf. Mason-Jones *et al.*, 2000). Elsewhere, Lean Six Sigma considers Lean practices and the emphasis of Six Sigma on the reduction of variation and variability (Näslund, 2008). More recently, the combination of the Lean philosophy and dynamic systems is advocated to cope with rapidly changing market dynamics and customer demands and conditions (cf. Ruffa, 2008).

Third, instead of solely focusing on shop-floor (manufacturing) processes, the contemporary Lean approach involves a holistic view of people, tools and technology (Bozdogan, 2010; Hines *et al.*, 2004; Liker and Morgan, 2006). In this light, the Lean philosophy has been studied from various perspectives (or domains), including culture (Mann, 2014), leadership (Mann, 2009), project management (Ballard and Howell, 2003), organizational change (De Toni and Tonchia, 1996), marketing (Piercy and Rich, 2009), information management (Hicks, 2007), accounting (Maskell *et al.*, 2011) and innovation management which is the focus of this paper.

Bel (2010, p. 47) defines innovation management as "developing a vision and a strategy, setting up the processes that will materialize it, and creating the organizational conditions and culture that will facilitate the emergence of ideas and their implementation." According to Morris (2011, p. 11), innovation is not only an outcome or attribute; it also involves the process of "developing ideas and turning them into valuable realities." Innovation management aims to create an environment for innovation to emerge, minimizing the cost of innovation process and maximize the value of innovative outcome at the level of individual innovation project (cf., Terwiesch and Ulrich, 2009; Trott, 2008). The management of innovation process, however, is frequently considered as a "black-box" (Guston, 2008), or in the words of Kline and Rosenberg (1986, p. 275) as "complex, uncertain, somewhat disorderly, subject to changes of many sorts, and difficult to measure."

Given that innovation management involves processes at various levels, that management of the innovation process is not straightforward and that Lean is focused on improving processes, an interesting and relevant question is how Lean principles and practices can spur innovation and help its management; a question that this study aims to address. Accordingly, the focus of analysis is neither on the broader field of Lean (i.e. beyond innovation) nor the wider field of innovation (i.e. beyond Lean), but on the intersection of both streams.

3. Research approach

To understand the complementarities between innovation management and the Lean philosophy, a systematic literature review was considered as a suitable research approach. Properly conducted, this approach is a systematic and replicable way to identify, evaluate and synthesize the existing body of knowledge of a given subject (Fink, 2005), while minimizes biases and errors and provides a transparent process (Transfield *et al.*, 2003).

As such, it has become a versatile method used in numerous contexts and published in high-quality scientific journals (Danese *et al.*, 2018). To ensure internal validity, the study followed the broadly accepted and frequently applied Okoli and Schabram's (2010) eight-step guideline:

- Step 1: purpose – as elaborated in Section 1, the core objective of the literature review was to explore how Lean philosophy contributes to innovation management.
- Step 2: protocol and training – the literature review process was initiated with a series of meetings wherein the reviewers (i.e. the first author together with two co-authors) established a consensus view on the purpose of the study, definitions (e.g. Lean, innovation management), data collection and structured analysis methods. The definitions, criteria, scope and procedure were captured in a detailed protocol.
- Step 3: search for literature – two dominant search engines were used: Social Science Research Network and Scopus. The search aimed to collect journal publications that include both "Lean" and "Innovation" in their title, abstract and/or keywords. To make sure that no relevant publication was overlooked, the search also included the key terms "R&D," "Start-up" and "NPD" as highly related to innovation; and "Toyota," "World Class Manufacturing" and "TPS" frequently associated with Lean philosophy. Accordingly, the following search query was formulated: ["Lean" OR "Toyota" OR "TPS" OR "Toyota Production System" OR "World Class Manufacturing"] AND ["Innovation" OR "R&D" OR "Research and Development" OR "NPD" OR "New Product Development" OR "Product Development" OR "Start-up"]. The search covered articles published between 1990 (when the seminal book by Womack *et al.* was published) and 2016 (data collection took place in 2017), and was limited to peer-reviewed journal publications in the English language. Once duplications had been removed, the search resulted in 785 references. To check the consistency and reliability of the output, several operations (e.g. *Journal of Operations Management*, *International Journal of Operations and Production Management*, *International Journal of Production Research*, *IEEE Engineering Management Review*) and innovation management (e.g. *Journal of Product Innovation Management*, *International Journal of Product Development*, *Creativity and Innovation Management*, *R&D Management*) publishers were independently screened.
- Step 4: practical screen – in the first selection round, the title, abstract and keywords of the papers were screened for relevance and 636 references were excluded. The articles excluded were those referring to chemical and clinical meaning of Lean, use lean as a verb or refer to Toyota in unrelated contexts, including Toyota sewing system, or other domains such as Thermal Power Station (TPS), Treatment-Planning System (TPS), Third Party Sales (TPS).
- Step 5: quality appraisal – the remaining 149 publications were subjected to full-paper screening to identify sources that explicitly relate Lean principles and practices to innovation or innovation management, further reducing the database to 80 articles. At this stage, the first author together with two co-authors read the entire publication and excluded those that refer to Lean or innovation management without expounding the relationship in-between. Reviewers also identified eight additional publications based on citations (five books and three articles), which were added to the database to bring the total literature review to 88 references.
- Step 6: data extraction – the selected papers were scrutinized in this step, for which keywords, phrases, sections and figures that explain how Lean philosophy may serve innovation or innovation management were collected in a database (made in Microsoft Excel spreadsheet). The database also captures additional information

including the papers' theoretical perspective, research domain, research method and sample size (if applicable). Although the first author was the main reviewer of the selected articles, to improve internal validity, a random subset of the articles were also reviewed by two co-authors. Iterative discussions among authors were needed to identify the reviewers' output deviations and to reach a complete unanimity on how to position the data in the database.

- Step 7: synthesis – the authors first reviewed the data to identify discern recurring themes within the data set (Miles and Huberman, 1994). In the continuation of the process, a "hub-and-spoke" structure emerged with the higher-order dimensions and constituting elements. Three authors have independently reviewed the publications and analyzed each other's outputs. After several iterations, the authors agreed on five dimensions that seemed to capture the higher-level structure of the data, each with several constituents. From this point, the authors persistently juxtaposed the remaining data with the initial model, and revised each time new insights were identified. Gradually, the model was polished to the point that no new insight could be added, suggesting that an acceptable "level of saturation" was reached. Throughout the process of synthesis, the authors constantly compared and discussed their outputs to reach consensus on the final classification, including categories, disciplines and the labels used.
- Step 8: write the review – the next section provides a detailed prescriptive and analytical account of the conducted literature review.

4. Five dimensions of Lean innovation

The trend of publication on Lean and innovation or innovation management appears to be growing (see Figure 1). Of the 88 articles and books reviewed, 47 percent are qualitative case studies (from which 23 articles are based on a single case), with another 18 percent being conceptual papers. Multi-method, survey, systematic literature review, (expert) interviews and content analysis constitute 15, 9, 7, 3 and 1 percent of the sample, respectively. In terms of the industry, 34 percent of the articles are industry-independent, followed by manufacturing (non-automotive), automotive, pharmaceutical and healthcare (17, 13, 9 and 5 percent, respectively). And the publishers with four or more articles on Lean and innovation management (or its subparts such as product development) are *International Journal of Computer Integrated Manufacturing*, *Research Technology Management*, *Drug Discovery Today* and *Harvard Business Review*. For more descriptive analysis of data, see Figure A1.

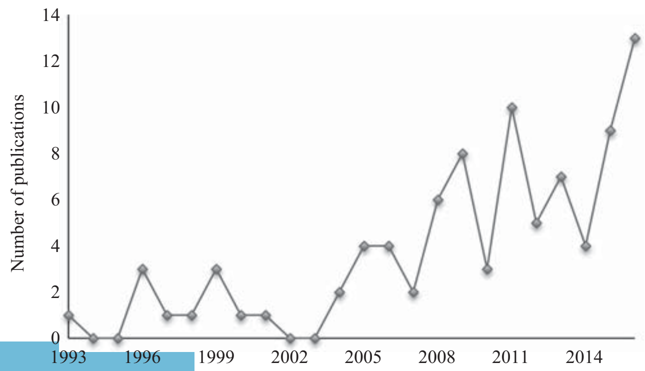

Figure 1.
Trend of publications between 1990 and 2016

Analysis of the data extracted in Step 7 above identified 34 Lean innovation practices and principles, which were classified into five dimensions: coaching, learning culture, collaborative internal structure, collaborative external networks and learning routines. The following sections describe the five dimensions in detail. Table I summarizes the key constructs, principles and practices for each dimension along with the relevant references.

4.1 Lean leadership (coaching)

Several researchers see Lean leadership as the missing link between harboring the ambition to become Lean and actually benefitting from it (Dombrowski and Mielke, 2013; Emiliani, 2008; Mann, 2009). With a focus on innovation, at least two main aspects of Lean leadership were underlined in the literature: "traits" to serve (as opposed to "Tayloristic" command and control), and "actions" as part of a Lean coach's "people system." To emphasize the Lean's unique way of management, the literature refers to coaches (or *sensei*). Although both traits and actions are naturally interrelated, for more clarity these aspects are discussed separately below.

Traits – servant leader. Lean innovation scholars appear to have a shared view of the Lean coach as respectful, inspiring and supportive (Adler, 1993; Boehm, 2012; Takeuchi *et al.*, 2008). Lean coaches obtain respect and trust from their employees by practicing what they preach (Adler, 1993), showing respect (Takeuchi *et al.*, 2008), they enjoy experimentation removing the perturbation associated with mistakes (Everett and Sitterding, 2013; Johnstone *et al.*, 2011; Ota *et al.*, 2013), and have a long-term vision and near-unattainable goals (Lindeke *et al.*, 2009; Polk, 2011).

Lean coaches are often on the work floor ("Gemba management") in order to be visible and actively observe and directly interact with employees (Boehm, 2012; Sehested and Sonnenberg, 2011). In this setting, communication skills appear critical, especially to provide transparency about the firm's strategic objectives and organizational changes (Boehm, 2012; Takeuchi *et al.*, 2008). Also, coaches' technical expertise appears to be equally important, not only to gain the trust and confidence of employees, but also to orchestrate cross-functional teams (Belt *et al.*, 2009; Harkonen *et al.*, 2009; Hoppmann *et al.*, 2011; Nepal *et al.*, 2011; Schuh *et al.*, 2011; Tyagi *et al.*, 2015). In short, Lean coaches are involved facilitators and not distanced "spreadsheet wonder managers" (Mintzberg, 2004).

Actions – people system. TPS system focused heavily on its human capital with the fundamental premise that "employees are not just viewed as pairs of hands but as knowledge workers who accumulate *chie* – the wisdom of experience – on the company's front lines" (Takeuchi *et al.*, 2008, p. 2). Dickson, *et al.* (2009) define the people system as "a system designed to provide the tools for people to continually improve their work and add value to the product or service they are producing." The idea is that Lean leader encourages employees to challenge the status quo, even by voicing contrarian opinions if necessary (Takeuchi *et al.*, 2008), facilitates them with the resources they need and guides them in their problem-solving endeavors (Adler, 1993; Aoki and Lennerfors, 2013; Nahmens and Ikuma, 2011), and servers as a "system integrator" who orchestrates project teams toward a synergistic whole (Morgan and Liker, 2006).

To maintain their relationship with employees, Lean leader remains in close dialogue with employees (Sehested and Sonnenberg, 2011), often short frequent daily huddles with examples and visualization (Evans and Wolf, 2005; Ward and Sobek II, 2014). Furthermore, apprenticeships is encouraged (Tyagi *et al.*, 2015), scheduling and trainings are based on skill maps (Boehm, 2012), and creativity is stimulated through fun contests (e.g. "Innovator of the Month"). Also, interaction with board-level managers seems to be stimulating (e.g. "periodic lunch with the firm chairman," Ozorhon *et al.*, 2013). In line with inner inclination toward experimentation (explained earlier), Lean leader seeks to remove the fear and

Constructs	Lean principle and practices in the context of Innovation	References
Coaching		
Servant leader	Trust-driven relationship (respect for employees)	Adler (1993), Boehm (2012), Evans and Wolf (2005), Mascarenhas Hornos da Costa *et al.* (2014)
	Clear communication about objectives based on both short-term and long-term vision (strategic, tactical, inspirational)	Antony *et al.* (2016), Boehm (2012), Byrne *et al.* (2007), Evans and Wolf (2005), Karlsson and Åhlström (1996), Lindeke *et al.* (2009), Polk (2011), Ries (2011), Smith *et al.* (1999), Takeuchi *et al.* (2008), Tan and Perrons (2009), Tyagi *et al.* (2015), Ward and Sobek II (2014)
	Management based on experience and mastery (technical competence)	Adler (1993), Belt *et al.* (2009), Harkonen *et al.* (2009), Hoppmann *et al.* (2011), Nepal *et al.* (2011), Schuh *et al.* (2011), Sehested and Sonnenberg (2011), Tyagi *et al.* (2015), Ward and Sobek II (2014)
People system	Leader's commitment to and engagement with innovation (willingness to change)	Adler (1993), Byrne *et al.* (2007), Lantz *et al.* (2015), Lindeke *et al.* (2009), Ozorhon *et al.* (2013), Sehested and Sonnenberg (2011), Sewing *et al.* (2008), Walker and Davies (2011)
	Empowering, encouraging and broadening people's perspective and knowledge (Gemba)	Antony *et al.* (2016), Adler (1993), Angelis and Fernandes (2012), Boehm (2012), Abuhejleh *et al.* (2016), Evans and Wolf (2005), Lindeke *et al.* (2009), Nahmens and Ikuma (2011), Nepal *et al.* (2011), Ota *et al.* (2013), Ozorhon *et al.* (2013), Radeka (2016), Reinertsen and Shaeffer (2005), Sakai *et al.* (2007), Tam *et al.* (2012), Tyagi *et al.* (2015)
	Discursive system-oriented guidance	Braczyk (1996), Everett and Sitterding (2013), Ota *et al.* (2013), Sehested and Sonnenberg (2011), Tyagi *et al.* (2015), Ward and Sobek II (2014)
	Taking away fear and frustrations	Antony *et al.* (2016), Angelis and Fernandes (2012), Everett and Sitterding (2013), Johnstone *et al.* (2011), Ota *et al.* (2013), Ozorhon *et al.* (2013), Takeuchi *et al.* (2008)
Learning culture		
Continuous improvement	Continuous improvement mindset (critical thinking)	Adler (1993), Al-Ashaab and Sobek II (2013), Barnhart (2008, 2016), Belt *et al.* (2009), Blank (2013), Browning and Sanders (2012), Abuhejleh *et al.* (2016), Harkonen *et al.* (2009), Johnstone *et al.* (2011), Morgan and Liker (2006), Radeka (2016), Sehested and Sonnenberg (2011), Takeuchi *et al.* (2008), Tan and Perrons (2009)
	Desire for excellence (confidence, risk-taking)	Adler (1993), Everett and Sitterding (2013), Haque and James-Moore (2004), Harkonen *et al.* (2009), Johnstone *et al.* (2011), Lindeke *et al.* (2009), Ota *et al.* (2013), Solleiro *et al.* (2016)
	Employee engagement (e.g. suggestion programs, celebrating success)	Adler (1993), Angelis and Fernandes (2012), Delbridge *et al.* (2000), Hines *et al.* (2006), Nicoletti (2015), Takeuchi *et al.* (2008)
	Deliberately initiated change (problem ownership)	Braczyk (1996), Sewing *et al.* (2008), Takeuchi *et al.* (2008), Tam *et al.* (2012), Wallace (2004)
Collectivism	Collective interest and accountability	Adler (1993), Bicen and Johnson (2015), Cooper and Edgett (2008), Morgan and Liker (2006), Ries (2011), Takeuchi *et al.* (2008), Wallace (2004), Ward and Sobek II (2014)
	Collaborative learning and problem solving	Al-Ashaab and Sobek II (2013), Barnhart (2016), Bicen and Johnson (2015), Delbridge *et al.* (2000), Hines *et al.* (2006), Lindeke *et al.* (2009), Nepal *et al.* (2011), Solleiro *et al.* (2016), Ståhl *et al.* (2015), Ward and Sobek II (2014)
Collaborative internal structure		
Self-regulative governance	Decision-making latitude (self-reliance and autonomy)	Angelis and Fernandes (2012), Braczyk (1996), Evans and Wolf (2005), Lantz *et al.* (2015), Ries (2011), Ståhl *et al.* (2015), Takeuchi *et al.* (2008)
	Decision-making across hierarchical layers of organization	Adler (1993), Boehm (2012), Lantz *et al.* (2015), Ota *et al.* (2013), Wallace (2004)
	Variegated job	Boehm (2012), Braczyk (1996), Wallace (2004)

Table I.
Framework conceptualization

(continued)

Constructs	Lean principle and practices in the context of Innovation	References
	Stimuli to engage and motivate	Boehm (2012), Braczyk (1996), Carleysmith *et al.* (2009), Evans and Wolf (2005), Delbridge *et al.* (2000), Sakai *et al.* (2007), Wallace (2004)
Process orientation	Value alignment between teams/departments	Barnhart (2008), Braczyk (1996), Byrne *et al.* (2007), Mascarenhas Hornos da Costa *et al.* (2014), Browning and Sanders (2012)
	Multidisciplinary teamwork (multi-skilled staff)	Angelis and Fernandes (2012), Barnhart (2008), Boehm (2012), Braczyk (1996), Cooper and Edgett (2008), Haque and James-Moore (2004), Hoppmann *et al.* (2011), Johnstone *et al.* (2011), Karlsson and Åhlström (1996), Khan *et al.* (2013), Lindeke *et al.* (2009), Nahmens and Ikuma (2011), Nepal *et al.* (2011), Ota *et al.* (2013), Ries (2011), Takeuchi *et al.* (2008), Tyagi *et al.* (2015), Walker and Davies (2011)
	Job rotation	Angelis and Fernandes (2012), Florida (1996), Ota *et al.* (2013), Sakai *et al.* (2007)
	Supportive cross-functional organizational setting (e.g. hybrid or matrix)	Belt *et al.* (2009), Boehm (2012), Evans and Wolf (2005), Harkonen *et al.* (2009), Morgan and Liker (2006), Sehested and Sonnenberg (2011), Ullman and Boutellier (2008), Ward and Sobek II (2014)
Collaborative external networks		
Customer centricity	Customer engagement	Bicen and Johnson (2015), Bieraugel (2015), Blank (2013), Cooper and Edgett (2008), Dal Forno *et al.* (2016), Florida (1996), Haque and James-Moore (2004), Karlsson and Åhlström (1996), Ozorhon *et al.* (2013), Pohl (2012), Ries (2011), Sehested and Sonnenberg (2011)
	Customer requirements	Belt *et al.* (2009), Boehm (2012), Byrne *et al.* (2007), Cooper and Edgett (2008), Gudem *et al.* (2014), Haque and James-Moore (2004), Hines *et al.* (2006), Hoppmann *et al.* (2011), Karlsson and Åhlström (1996), Mascarenhas Hornos da Costa *et al.* (2014), Nahmens and Ikuma (2011), Nepal *et al.* (2011), Nicoletti (2015), Pohl (2012), Reinertsen and Shaeffer (2005), Ries (2011), Sakai *et al.* (2007), Schuh *et al.* (2011), Sehested and Sonnenberg (2011), Tam *et al.* (2012), Walker and Davies (2011)
Supplier development	Partnership with other stakeholders	Bidault *et al.* (1998), Bruce and Moger (1999), Byrne *et al.* (2007), Haque and James-Moore (2004), Harkonen *et al.* (2009), Karlsson and Åhlström (1996), Kinkel and Som (2010), Lantz *et al.* (2015), Morgan and Liker (2006), Ota *et al.* (2013), Smith and Tranfield (2005), Tam *et al.* (2012), Tuli and Shankar (2015)
	Initiatives with suppliers (e.g. education, loyalty programs, NPD, JIT/Kanban)	Angelis and Fernandes (2012), Aoki and Lennerfors (2013), Bidault *et al.* (1998), Morgan and Liker (2006), Ozorhon *et al.* (2013)
	Knowledge exchange with suppliers (e.g. study groups, collaborative problem solving)	Aoki and Lennerfors (2013), Belt *et al.* (2009), Dyer and Hatch (2006), Evans and Wolf (2005), Florida (1996), Hoppmann *et al.* (2011), Lantz *et al.* (2015), Nepal *et al.* (2011), Ozorhon *et al.* (2013), Pohl (2012), Smith and Tranfield (2005), Tan and Perrons (2009), Tuli and Shankar (2015), Ullman and Boutellier (2008), Ward and Sobek II (2014)
Learning routines		
Efficient learning	Waste reduction	Carleysmith *et al.* (2009), Cooper and Edgett (2008), Haque and James-Moore (2004), Helander *et al.* (2015), Karlsson and Åhlström (1996), Lindeke *et al.* (2009), Mascarenhas Hornos da Costa *et al.* (2014), McManus (2005), Nepal *et al.* (2011), Reinertsen and Shaeffer (2005), Schuh *et al.* (2011), Sehested and Sonnenberg (2011), Smith *et al.* (1999), Ward and Sobek II (2014)
	Standardization (reducing unnecessary variability)	Adler (1993), Belt *et al.* (2009), Haque and James-Moore (2004), Harkonen *et al.* (2009), Helander *et al.* (2015), Hines *et al.* (2006), Hoppmann *et al.* (2011), Khan *et al.* (2013), Letens *et al.* (2011),

(continued)

Table I.

Constructs	Lean principle and practices in the context of Innovation	References
		Morgan and Liker (2006), Nepal *et al.* (2011), Polk (2011), Sakai *et al.* (2007), Schuh *et al.* (2011), Sehested and Sonnenberg (2011), Sewing *et al.* (2008)
	Process flow	Carleysmith *et al.* (2009), Boehm (2012), Haque and James-Moore (2004), Harkonen *et al.* (2009), Helander *et al.* (2015), Hoppmann *et al.* (2011), Letens *et al.* (2011), McManus (2005), Morgan and Liker (2006), Nepal *et al.* (2011), Rauch *et al.* (2016), Reinertsen and Shaeffer (2005), Sewing *et al.* (2008), Ullman and Boutellier (2008), Walker and Davies (2011), Ward and Sobek II (2014)
	Prioritization (e.g. funneling, project portfolio, delayed decision making)	Al-Ashaab and Sobek II (2013), Belt *et al.* (2009), Cooper and Edgett (2008), Hoppmann *et al.* (2011), Johnstone *et al.* (2011), Letens *et al.* (2011), Morgan and Liker (2006), Nepal *et al.* (2011), Ries (2011), Sehested and Sonnenberg (2011)
Effective learning	Value (definition, perception, expectation)	Belt *et al.* (2009), Browning and Sanders (2012), Cooper and Edgett (2008), Harkonen *et al.* (2009), Hines *et al.* (2006), Khan *et al.* (2013), Letens *et al.* (2011), Mascarenhas Hornos da Costa *et al.* (2014), McManus (2005), Ries (2011), Sehested and Sonnenberg (2011), Ward and Sobek II (2014)
	Rapid iterative experiments	Blank (2013), Cooper and Edgett (2008), Helander *et al.* (2015), Johnstone *et al.* (2011), Leite *et al.* (2016), Nepal *et al.* (2011), Nicoletti (2015), Pohl (2012), Ries (2011), Sehested and Sonnenberg (2011), Smith *et al.* (1999), Takeuchi *et al.* (2008)
	Scientific problem-solving (root-cause analysis, PDCA, set-based concurrent engineering, value stream mapping, visual management, hypothesis-driven, metrics)	Adler (1993), Al-Ashaab *et al.* (2013), Al-Ashaab and Sobek II (2013), Barnhart (2008, 2016), Belt *et al.* (2009), Biazzo (2009), Bicen and Johnson (2015), Bieraugel (2015), Blank (2013), Browning and Sanders (2012), Carleysmith *et al.* (2009), Cooper and Edgett (2008), Evans and Wolf (2005), Haque and James-Moore (2004), Harkonen *et al.* (2009), Helander *et al.* (2015), Hines *et al.* (2006), Hoerl and Gardner (2010), Hoppmann *et al.* (2011), Khan *et al.* (2013), Kinkel and Som (2010), Leite *et al.* (2016), Letens *et al.* (2011), Majerus (2016), Mascarenhas Hornos da Costa *et al.* (2014), McManus (2005), Morgan and Liker (2006), Nepal *et al.* (2011), Nicoletti (2015), Pohl (2012), Polk (2011), Radeka (2016), Raudberget (2010), Reinertsen and Shaeffer (2005), Ries (2011), Sakai *et al.* (2007), Sehested and Sonnenberg (2011), Sewing *et al.* (2008), Smith *et al.* (1999), Sobek *et al.* (1999), Ståhl *et al.* (2015), Stonemetz *et al.* (2011), Tam *et al.* (2012), Tortorella *et al.* (2016), Tyagi *et al.* (2015), Ullman and Boutellier (2008), Ward and Sobek II (2014)
	Knowledge management (information generation, sharing, use and reuse)	Al-Ashaab *et al.* (2016), Al-Ashaab and Sobek II (2013), Belt *et al.* (2009), Evans and Wolf (2005), Gudem *et al.* (2014), Helander *et al.* (2015), Hines *et al.* (2006), Hoppmann *et al.* (2011), Lindeke *et al.* (2009), Morgan and Liker (2006), Pohl (2012), Sehested and Sonnenberg (2011), Tortorella *et al.* (2016), Ward and Sobek II (2014)

Table I.

frustration that potentially stem from making mistakes, promote risk-taking attitude, ask questions and calls for self-reflection and constructive criticism (e.g. Angelis and Fernandes, 2012; Everett and Sitterding, 2013; Johnstone *et al.*, 2011).

4.2 Learning culture

The second dimension is a learning culture where the literature emphasizes at least two aspects; a continuous improvement mindset and collectivistic behavior.

Continuous improvement mindset. Several authors stress the importance of continuous improvement "mindset" (Kaizen in Lean terms) (e.g. Adler, 1993; Blank, 2013; Johnstone *et al.*, 2011) which refers to a ceaseless inner urge to strive for perfection, ingrained at an individual level. Employees are "change agents" and have a sense of "problem ownership"; they are willing to take responsibility and act autonomously (Braczyk, 1996; Ota *et al.*, 2013; Sewing *et al.*, 2008). This is achieved through critical thinking and by challenging the established order and structure of the firm's policies, standards, processes and solutions (Barnhart, 2008). It should be noted that continuous improvement mindset is not limited to incremental innovation; Bicen and Johnson (2015) point out that the Lean innovation capability enable firms to unlock radical innovation by a more effective reconfiguration and reallocation of existing resources.

What is more, authors addressing learning culture observe that where continuous learning is a collective norm; it is more actively nurtured (Everett and Sitterding, 2013; Johnstone *et al.*, 2011). In that sense, Lean innovation does not rely so much on traditional monetary "carrots" and control "sticks" to encourage engagement (Evans and Wolf, 2005), but employs subtle stimuli, including public recognition (Boehm, 2012; Carleysmith *et al.*, 2009), peer admiration (Evans and Wolf, 2005), suggestion schemes (Adler, 1993; Delbridge *et al.*, 2000), celebration of day-to-day successes (Hines *et al.*, 2006; Sewing *et al.*, 2008) and sharing and pursuing an innovation agenda across the company and beyond (Byrne *et al.*, 2007); all to create a climate where continuous learning is instinctive.

Collectivism. Another feature of learning culture appears to be prioritization of team interests over individual interests. According to Tyagi *et al.* (2015), knowledge is a "dynamic gain" based on team members' interactions, problem-solving actions and tasks performed. Adler (1993) argues that Toyota's well-known no-layoff policy not only removed workers' fear of losing their job, it also reinforced the firm's team culture, where problem-solving is not individualistic, but endemic in the teams made up of individuals (Wallace, 2004), and where teams feel safe to practice *hensei* (reflection) to identify mistakes and take responsibility for rectifying and improving on them (Morgan and Liker, 2006). Knowledge is a "relational asset" (Bicen and Johnson, 2015) that is generated and disseminated through multidisciplinary teamwork and collaborative problem-solving, as well as informal relationships (Lindeke *et al.*, 2009; Nepal *et al.*, 2011; Ståhl *et al.*, 2015; Takeuchi *et al.*, 2008).

4.3 Collaborative internal structure

For a Lean innovation to emerge, the literature calls for a collaborative organizational structure with two underpinning ingredients: process orientation and self-regulative governance.

Process orientation. The Lean innovation literature deplores departmentalization; instead, it calls for cross-functional and cross-sectional, multidisciplinary collaborative structure (Braczyk, 1996; Karlsson and Åhlström, 1996; Walker and Davies, 2011) to create customer value (Ståhl *et al.*, 2015). As such, as a focal orientation, value streams are preferred over departments. Fiore (2005) describes the value stream as "the connection between all the process steps with the goal of maximizing customer value." Hence, firms' performance can better be measured by considering the whole operations rather than the sum of its parts (Browning and Sanders, 2012). Accordingly, the product portfolio and development pipeline toward innovation efforts are encouraged to be assessed by a multidisciplinary team made up of R&D, sales, finance, planning and control with an eye on profitability, customer value, strategic relevance and available resources (Boehm, 2012; Sehested and Sonnenberg, 2011).

Although the literature on exact structure of Lean innovation organization is limited, modular teaming and hybrid (or matrix) organization have received the most attentions. The former refers to teams focusing on small, simple tasks that together make up a larger whole (Evans and Wolf, 2005). The latter proposes paired teams of experts in which one team focuses on intense knowledge creation and hypothesis formulation (innovation studio), while the other is responsible for data generation and hypothesis-testing (process factory)

(Ullman and Boutellier, 2008). A different interpretation of hybrid organization is a dichotomy between horizontal process coordination and vertical functional management (Boehm, 2012). Ward and Sobek II (2014) oppose the negative connotation of the "working-for-two-bosses" trademark, and emphasize that such a structure enables a collaborative environment where project managers and functional leaders support each other, while remain closely in touch with the board-level management and front-line developers. That said, it is a delicate task to overcome likely conflict of interest between functional department and task-oriented projects (Karlsson and Åhlström, 1996; Morgan and Liker, 2006).

Self-regulative governance. Rather than being entirely top-down, from the Lean innovation perspectives, employees enjoy a fair amount of decision-making latitude (Ståhl *et al.*, 2015). The firm's goals are broken down into concrete milestones to be agreed upon by employees through continuous dialogue, negotiation and consensus-building, and employees are free to stipulate their own roadmap as long as they meet the agreed upon deadlines (Karlsson and Åhlström, 1996; Morgan and Liker, 2006; Ota *et al.*, 2013). In describing the Lean transformation of a R&D division, Boehm (2012) highlights the bottom-up effort of employees by, for instance, developing and testing process improvement ideas and spreading the best practices across the organization. At a strategic level, in TPS, *hoshin kanri* (strategy deployment) was a to gain consensus on management targets and measures at all levels of the firm through bottom-up feedback in an iterative "catch-ball" process (Hutchins, 2008; Tennant and Roberts, 2001).

Furthermore, self-regulatory teamwork is encouraged by variegated job description, e.g., assigning a combined set of execution and executive tasks to employees to encourage self-regulation, especially if performance is subjected to self-evaluation (Braczyk, 1996); and "sense of ownership" (Angelis and Fernandes, 2012; Wallace, 2004), e.g., establishing "temporary think tank" where creative employees are taken away from their routine work, organized in teams, on a temporary basis, and encouraged to develop and test creative ideas and remain accountable for product rollout (Lindeke *et al.*, 2009).

4.4 Collaborative external networks

TPS did not merely rely on its internal improvement potentials; its outward collaborative orientation has been an important, yet often overlooked, factor in its success (Aoki and Lennerfors, 2013; Bidault *et al.*, 1998; Liker and Choi, 2004). In this regard, two aspects stood out: customer centricity and supplier development.

Customer centricity. Schuh (2013) posit that invention becomes innovation when it creates value for a customer. However, customer needs are often latent, dynamic and not unambiguously expressed (Bicen and Johnson, 2015; Cooper and Edgett, 2008; Letens *et al.*, 2011). TPS therefore positioned the customer as an integral part of its development process (Cooper and Edgett, 2008), proactively explored their needs (Ota *et al.*, 2013), through feedback loops (Reinertsen and Shaeffer, 2005) and carefully planned experiments to systematically elicit customers' desires and requirements (Bieraugel, 2015; Ries, 2011). Note that the emphasis is not only on "utilitarian" values (i.e. rational values that are independent of the observer or users), but also on "emotional" values (i.e. subjective experiential attributes dependent on the opinions, feelings and perceptions of observers or users) (Gudem *et al.*, 2014; Gülyaz *et al.*, 2019).

Supplier development. TPS seems to have benefitted from its early engagement with its suppliers, based on long-term relationship, information sharing, co-creation and collaborative innovation (Aoki and Lennerfors, 2013; Bidault *et al.* 1998; Bruce and Moger, 1999; Smith and Tranfield, 2005). Various initiatives helped to stimulate positive supplier relations, including loyalty plans, educational programs and traineeship involving supply chain partners, cross-company teams, collaborative R&D activities, multilateral agreements to centralize and exchange information and knowledge, to name a few (Bidault *et al.*, 1998; Harkonen *et al.*, 2009; Nepal *et al.*, 2011; Smith and Tranfield, 2005; Tam *et al.*, 2012; Tan and Perrons, 2009; Tuli and Shankar, 2015).

To explain collaborative Lean innovation, Wallace (2004) underlines Edquist's (2001) concept of "interactive learning," which is driven by interactions and knowledge exchange between firms involved in innovation processes (for instance, Toyota invites guest engineers from its suppliers; Morgan and Liker, 2006). Other benefits of supplier development are: accrued collective knowledge is tacit and dispersed across complex webs of inter-organizational interactions that cannot easily be acquired or copied by competitors (Bicen and Johnson, 2015), collaborative partnering accelerates the process of innovation diffusion among the involved actors (Ozorhon *et al.*, 2013) and radical innovation can be enabled through collaboration, particularly when practiced at a global scale (Tan and Perrons, 2009).

4.5 Learning routines

Finally, Lean innovation is closely related to learning and various tools and techniques can help to make the learning process more efficient and effective.

Efficient learning processes. With respect of efficiency, two key components of Lean innovation, namely, waste elimination through standardization and improved process flow are frequently put forward (Morgan and Liker, 2006). Both of these help to free up resources, which in turn, are to be re-invested in creativity-demanding, non-repetitive (often knowledge-generating), difficult to standardized activities (Adler, 1993; Schuh, 2013; Sewing *et al.*, 2008).

Administrative activities such as meetings, documentation and reporting (Schuh, 2013) and training of new employees and use of equipment (Sewing *et al.*, 2008) are some areas conducive to standardization. Process flow refers to "rhythmic" cycles of activities with minimum interruptions (sometimes referred to as "cadence"; Ward and Sobek II, 2014), and it can be achieved by limiting and prioritizing the number of projects (e.g. portfolio management, kanban project phasing[1]) (Boehm, 2012; Cooper and Edgett, 2008; Helander *et al.*, 2015), minimizing "undesirable"[2] process variability (Nepal *et al.*, 2011), establishing a "pull" system to prevent process variation (Reinertsen and Shaeffer, 2005), staggering projects to level the workload (or *Heijunka* in Lean terminology) (Hoppmann *et al.*, 2011), keeping project handoffs at a minimum (Nepal *et al.*, 2011), flexible staffing (Morgan and Liker, 2006) and avoiding any scatter effect such as distracted developers, unavailable resources or disrupted communication (Nepal *et al.*, 2011; Ward and Sobek II, 2014). Furthermore, small-scale batch-sized experiments (Ries, 2011; Reinertsen and Shaeffer, 2005), as well as a clean and organized workplace (Sewing *et al.*, 2008) can improve flow.

Effective learning processes. The effective learning process refers to the value or applicability of learning outcomes, e.g., deducing insight from testing process to initiate succeeding testing iterations, augmenting product functionalities in close consultation with users and sharing captured knowledge across the organization wherever and whenever needed (Sehested and Sonnenberg, 2011). To enhance effectiveness, learning process is to be structured with a clear scope and objectives (Ries, 2011); it is not about unfettered exploration, but rather a systemic and controlled process of hypothesis-testing (Biazzo, 2009; Ries, 2011), or in the words of Smith *et al.* (1999) "guilty-until-proven-innocent" assumptions. Hence, experimentation is not a "shot in the dark"; it is virtually a scientific problem-solving process backed up with validated data (Bicen and Johnson, 2015; Bieraugel, 2015; Nepal *et al.*, 2011; Sewing *et al.*, 2008), starting with a solid understanding of customer expectations of value and anti-value (Browning and Sanders, 2012; Cooper and Edgett, 2008;

Helander *et al.*, 2015; Letens *et al.*, 2011; Mascarenhas Hornos da Costa *et al.*, 2014), and aiming to fill knowledge gaps with quick iterations of small-scale experiments (e.g. rapid prototyping, simulation or minimum viable products) (Blanks, 2013; Hoppmann *et al.*, 2011; Ries, 2011).

Such learning process calls for a systematic approach, which can be managed with tools and techniques such as Plan-Do-Check-Act (PDCA) (the Deming wheel) to systematize the learning process and collect users' early feedback; various root-cause analysis techniques such as 5 Whys, Fishbone diagrams, trade-off curves and cross-checking; set-based concurrent engineering to allow for more alternative solution-testing, while delaying certain decisions until sufficient insight is achieved before narrowing down (also called front-loading); visualization techniques (e.g. value stream mapping, spaghetti diagram); and metrics and performance indicators (e.g. patent metrics, cycle-time, revenue projection, quality index) to steer processes, measure results and, particularly, communicate in a stimulating way (e.g. Adler, 1993; Carleysmith *et al.*, 2009; Cooper and Edgett, 2008; Helander *et al.*, 2015; Hoppmann *et al.*, 2011; Khan *et al.*, 2013; Nepal *et al.*, 2011; Pohl, 2012; Ries, 2011; Sewing *et al.*, 2008; Smith *et al.*, 1999; Ståhl *et al.*, 2015; Stonemetz *et al.*, 2011; Tam *et al.*, 2012).

In addition, the literature draws attention to knowledge management, i.e., how to effectively capture, store, organize, categorize, update data/knowledge pool and make data/knowledge accessible whenever and wherever needed (Hoppmann *et al.*, 2011; Khan *et al.*, 2013; Morgan and Liker, 2006). Some areas where knowledge management appears to be critical are knowledge transfer between running projects (Hines *et al.*, 2006; Cusumano and Nobeoka, 1998), knowledge retention (e.g. by keeping their technical experts much longer in their technical position before moving them toward general management) (Hoppmann *et al.*, 2011), elicitation of critical tacit knowledge (Belt *et al.*, 2009).

5. The Leanovation framework

With a bird's-eye view on the five dimensions as discussed in the previous Section 2 important observations can be made. First, each dimension requires a set of multilayered ambidextrous capabilities including: employees' collective accountability vs a self-regulatory work setting (culture vs structure), efficiency vs effectiveness in learning processes (learning routines), exploration vs exploitation together with stakeholders (internal and external collaboration) and competent leadership that stimulates a culture of innovation while managing and monitoring learning routines and practices. This suggests that management teams do well to be aware of this ambidexterity, and strive to not overly emphasize one side or the other.

Second, although each the five dimensions in the previous section are discussed independently, the data also indicate that they mutually support and reinforce one another. The so-called "Leanovation framework" as shown in Figure 2 attempts to describe such connectivity between the dimensions. Below the various connections between the dimensions (i.e. the arcs in Figure 1) will be shortly discussed.

As part of collaborative internal structure, multidisciplinary teams with self-regulative authority can perpetuate a mindset and attitude of accountability and continuous improvement across the organization. At the same time such a mindset and attitude help to uphold and enhance the desire among employees for collaboration with cross-functional colleagues and their willingness to fully benefit from organizational non-confinement in their decision-making. As part of learning routines, several tools and practices can be employed, mainly to cater for a more efficient and effective learning process, which can be enriched with the involvement of and feedback from the value chain. In turn, the released value can be co-appropriated by the involved stakeholders in terms of higher quality and novel products and services, optimized operations and knowledge

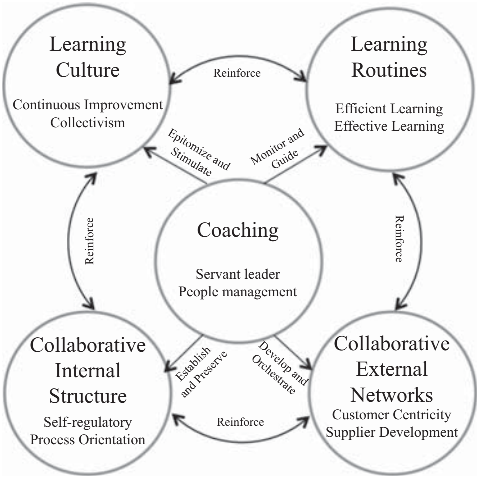

Figure 2.
The Leanovation framework

spillover (Gülyaz, 2017). The learning culture spurs staff on to use learning routines, while applying the routines institutionalizes learning within the culture. Likewise, a collaborative intra-organizational structure can be seen as a cognitive preparation of inter-organizational collaboration, which in turn helps to further establish a collaborative working routine. In this sense, there is a reinforcing effect between the four dimensions of innovation management.

The literature on Lean innovation considers coaching as an adhesive force between – and a facilitator of – all four other dimensions. Lean innovation coaching is marked by a synergetic combination of technical competence, visionary thinking, a trust-driven relationship with employees, keen to serve employees by accommodating them with resources and supporting them in their problem-solving endeavors. It emphasizes the importance of suppliers and customers, orchestrating their involvement in R&D activities. In terms of internal organization, the Lean coach empowers employees, thus steering them toward self-development, self-regulation and self-reliance on their path of "learning how to learn" and "continuous persuasion of perfection." The Lean coach therefore establishes and maintains process orientation, which means that inter-disciplinary cross-functional network of inter/intra-organizational actors collaborate to serve the downstream customer. Such an organizational structure enables and is reinforced by a learning culture with an everlasting thirst for creativity. The Lean innovation leader fulfills an indispensable role, feeding this culture by acting as the epitome of Lean principles and practices, and actively guides and encourages others in adopting an explorative, inquisitive mindset, committed to continuous learning, along with a collectivistic attitude.

6. Discussion

In the era of "innovate or perish," understanding the mechanics of innovation is increasingly important. Innovation capability does not come automatically; studies point out that it is the outcome of effective and efficient management of innovation processes. The Lean philosophy has proven to be a potential way to boost firms' innovation capability, by first, "doing the right thing," and then "doing it right," and finally "doing it better" all the time (Sehested and Sonnenberg, 2011, p. 3). The interest in Lean innovation has been immense, leading to many scholarly publications in this area, and inevitably, a miscellaneous collection of concepts, principles and practices that aim to shed light on how Lean can be applied in the innovation management context.

Contributing to the existing socio-technical conception of Lean (Hadid *et al.*, 2016; Johnstone *et al.*, 2011; Tortorella *et al.*, 2016), this study integrates the literature into a comprehensive framework consisted of cultural, relational, organizational, technical and leadership attributes. It is not the attributes in isolation that describe the Lean innovation system, but the reinforcing and synergistic effect in-between. Such a socio-technical system requires ambidextrous capabilities which underline firms' ability to simultaneously pursue exploitation and exploration (i.e. incremental improvement of current operations and exploration of new breakthrough innovation) (Tushman, 2004). Gibson and Birkinshaw (2004) refer to "structural" ambidexterity where firm creates "dual structure" to accommodate exploitation and exploration separately, and "contextual" ambidexterity where firms adopt a simultaneous adoption of exploration and exploitation (or alignment and adaptability) across an entire business unit.

In the context of Lean implementation, Secchi and Camuffo (2019) advocate a "situational" approach in choosing between structural and contextual ambidexterity – that is, the choice between structural and contextual ambidexterity is contingent upon several variables, including the type of business, the company size, the company's strategic goal, the size of targeted performance improvement. The synergistic relationship between Lean principles and practices discussed in this study, however, call for a more contextual ambidexterity where both soft and hard factors are simultaneously embedded in all layers of organization regardless of firms' contingencies. It is evident, however, that more empirical evidence is needed in exploring the role.

7. Managerial implications

Taking an organizational perspective, managers and practitioners are suggested to combine both "soft" (e.g. learning culture, collaborative attitude) and "hard" (e.g. learning routines, collaborative organizational structures) aspects of Lean philosophy, ensure coherence and alignment between soft and hard factors and train managers to be supportive, inspiring, respectful and trustworthy coaches, committed to the Lean journey, linking pin between employees, focused on learning, with a clear vision. The proposed framework can stimulate firms toward a well-balanced Lean innovation system where both the soft and hard aspects are equally considered and synergistically interconnected.

Without any model validation pretense, Table II provides three illustrative cases from healthcare, electronics and avionics industries, to which the Leanovation framework is applied. It can be observed that in the case of public hospital there can be more emphasis on employees' (autonomous) teamwork and concomitant collaborative mindset; in the electronics company case, leadership seems to be limited to awareness programs and Gemba management, and in the case of the avionics manufacturer, additional trainings around Lean learning tools and techniques may stimulate the firm's overall innovation culture.

8. Limitations and future work

To the best of our knowledge, this study is the first to systematically review the existing body of knowledge on the application of the Lean philosophy for innovation management. That being said, the findings of this study are limited by the specific research method that was used (e.g. more articles and books could have been collected by accessing more publishing networks, using more search keys or applying fewer exclusion criteria). The work is further limited by the conceptual nature of the study, which suggests that further empirical validation is needed. For instance, engaging in action research to study how the framework may help firms to improve their innovation capability, i.e., assessing the frameworks impact on innovation performance by means of quantitative studies (Solaimani *et al.*, 2019).

Case (references)	Coaching	Learning culture	Collaborative internal structure	Collaborative external networks	Learning routines
Public hospital: innovative solution to meet the guidelines regarding arrival-to-treatment interval for cardiovascul-ar patients in a public hospital in the UAE (Abuhejleh *et al.*, 2016, pp. 29-30)	Servant leader A committed team of senior leaders implementing reverse pyramid model of leadership Engaging the front-line staff and caregivers to improve the processes they own People management Reviewing and recognizing the staff and the processes Focus on problem-solving and engagement of front-line caregivers and managers Gemba walks as a sign of respect to staff	Continuous improvement Improving the hospital culture through bottom-up decision-making, caregivers' empowerment, shared communication, and considering the patients' interests as top priorities Engaging everyone in continuous improvement (identifying and solving problems) to stimulate a long-term patient-driven improvement mindset Collectivism Collaborative problem-solving leading to a culture supportive of quality improvement with joint effort Celebrating success	Process orientation Multidisciplinary teams who involved stakeholders early in the process Quality improvement by employee involvement across all levels Self-regulatory Staff evaluation of as-is workflow (including suboptimal communication with physicians, pharmacy space distribution) while seeking for process inefficiencies	Customer centricity Focus on patients' satisfaction (e.g. patients "access and waiting time"), which granted a sense of urgency and support to initiate a complete change process with ambitious goals Supplier development Besides substantial reduction in waiting time, the biggest achievement of the Lean transformation was empowering and engaging the pharmacy staff from day one, leading to increased morale and satisfaction, boosted self-confidence, and unleashed creativity	Efficient learning Comprehensive analysis of the data to identify waste and barriers to flow (e.g. communication channels between various departments, shortcomings in outpatient's pharmacy process) Effective learning Applying PDCA cycles and continuous testing by piloting the ideas on the ground before selection and rollout Training and developing staff in Lean tools and techniques (e.g. VSM trainings) By using the measurements at every step in projects and adding them to VSM, the teams excelled at brainstorming and deep analyses
Philips: full-fledged transformation to Lean innovation on a global scale (Ende, 2014; ICSB Report, 2014; Philips Innovation Services, 2016a, b)	Servant leader Not only looking into the solutions but also how solutions has come into existence Managers are "coaches" and stimulate	Continuous improvement Stimulating staff toward a continuous improvement mindset Lean behavioral development for staff and teams Collectivism	Process orientation Integration of more departments in Lean transformation until the entire organization is involved Embedding an end-to-end process view into	Customer centricity Voice-of-customer in the early development stage (e.g. the needs of the "crowd" via social media) to minimize failures and optimize "conversion" in later stages	Efficient learning Eliminating the waste of unnecessary duplications and "re-inventing the wheel" to facilitate "rapid learning cycles" Increasing extent of standardization of the

(*continued*)

Table II.
Deployment of Leanovation framework in three illustrative cases

Table II.

Case (references)	Coaching	Learning culture	Collaborative internal structure	Collaborative external networks	Learning routines
	improvement initiatives Committed and engaged management team Coaches attended awareness programs and trainings People management Gemba walk as a frequent ritual of (executive) leaders to see the problems and work together with small teams	Defining the innovation process to ensure transparency, and create a sense of unity among departments, disciplines and business units Focus on cross-departmental alignment	management and reporting structure to eradicate inefficiencies caused by departmentalization Facilitating small entrepreneurial, multidisciplinary teams or "cells" Self-regulatory Encouraging staff (informal) collaborative problem-solving as part of their daily work	Supplier development Expanding the Lean organization by involving suppliers and co-developers in the product development process Open community with architects, hobbyists to work with Philips' interconnected and intelligent lighting systems Horizontal collaboration with actors beyond the supply network, such as CitizenM (which is an innovative hotel chain)	development processes (in fact, even a good portion of leaders tasks are standardized) Using "kamishibai" boards as visual audit needed to sustain standards Effective learning Lean innovation is about two value streams: product development (ideation to commercialization) and knowledge value stream (knowledge generation, capture, store and reuse) at the base of product development For each problem, the developer seeks the corresponding "knowledge holder" that can be found in consultation with a dedicated "knowledge team" (with eight members, each with its own expertise) responsible for connecting knowledge supply and demand "Critical question mapping" and "set-based engineering" to focus on knowledge gaps

(*continued*)

Case (references)	Coaching	Learning culture	Collaborative internal structure	Collaborative external networks	Learning routines
Rockwell Collins: a Lean innovation- centric enterprise (Barrett and Long, 2003; Srinivasan, 2010, pp. 387-393)	Servant leader Creative leader who can create a right team with right capabilities (integrator) Supportive attitude toward innovation and innovators Securing leadership commitment to support and drive enterprise behavior People management Mentoring program to help employees gain professional skills and insight Senior managers involved in active, periodic on-the-job interactions Consistent funding for innovation activities	Continuous improvement Financial incentives and peer recognition (e.g. "Corporate Engineer of the Year") to encourage everyone to spot opportunities and trends related to their own work Introduction of "10X" program to encourage the staff to submit high-risk ideas with ten times larger impact on cost, size or power requirements Collectivism Using performance metrics that points to the general effectiveness of R&D and serves as a rallying point around which multiple groups can coalesce Supporting the development of "communities of practice" among engineers	Process orientation Stimulating staff to have a "big picture perspective" so they understand their impact on the whole value stream Creating shared value proposition across the enterprise on the role and value of innovation Self-regulatory Career trajectories to enable staff to grow within a technical role and take on greater responsibility to drive, support, and manage innovation efforts Funding employees ideas and allowing them to develop their proof-of-concept and once proven viable, join the R&D pipeline	Customer centricity Adopting customer focus as the organization value Customers' needs and expectation embedded in teams' goals Access to technologies that enable flexibility to respond to customers' needs Supplier development Adopting "open innovation" as an approach to collaborate with stakeholders involved in innovation process Involving multiple (internal and external) stakeholders in the enterprise innovation system (e.g. product development and trainings with vendors)	Efficient learning Designing various e-learning modules and computer-based trainings to enable staff use their time efficiently while enjoying the trainings Effective learning Support organizational learning with knowledge management programs Changing the learning culture from static classroom training to "learner-controlled" setting in which the learner decides what, when, how much Co-location of engineers with production team to facilitate cross-functional learning Informal "brown bag lunches" among mechanical engineers or functional teams who do their own research

Table II.

Equally important is to study the interrelationships and interaction between various dimensions of Lean innovation system. It is worth to note that the socio-technical duality of literature appeared in this study is in line with the existing conception of Lean "system" (Hadid *et al.*, 2016; Soliman and Saurin, 2017). However, such a systemic view gives rise to new questions including how the interaction effects work, i.e., in what combination the "sum of the parts is greater than the whole"? Worded differently, how the sociocultural aspects reinforce the techno-processual interventions? Particularly, the role of leadership as a catalyst in effectuating the proposed framework requires more attention.

Another interesting area of study is the impact of the firm's context on the model, such as firms in dynamic vs stable markets, product vs service industries, knowledge intensive vs labor intensive settings, SMEs vs large enterprises. The aim is to understand how effective the proposed framework is various contexts? After all, there is no one-size-fits-all approach in management of innovation; it is in fact contingent on a broad range of firms' internal and external factors (e.g. Tidd, 2001). This study provides the overall structures, and a long list of promising principles and practices that "modularly" can be combined to address the firms' specific context and peculiarities. That said, Lean may not always be applicable (Andersson *et al.*, 2006); further research is needed to address possibly conflicting views on Lean innovation management and other approach to innovation management. Finally, Lean is considered as a gradual transformation (Boehm, 2012). Accordingly, future studies can focus on the Lean innovation management "transformation process" and how it can be monitored and evaluated along a maturity model.

Finally, while in qualitative terms the volume of literature on "learning routines" hints that scholars have mainly focused on Lean tools and techniques (see Table I: learning routines); hence, further research is needed to develop a more refined understanding of the less tangible (or soft) aspects of Lean innovation management.

Notes

1. The Kanban rule permits a limited number of simultaneous projects at various stages of product development, e.g., backlog, in progress, built, validated (Ries, 2011).
2. In contrast to manufacturing settings, where variability is conventionally ruled out, R&D may benefit from variability and hence "desirable" and "undesirable" variability need to be distinguished from one another (Reinertsen and Shaeffer, 2005). For instance, as part of drug discovery process, generation of more substance variants (i.e. compound design) is desirable, but undesirable is any variation in measurement of substance properties (Walker and Davies, 2011).

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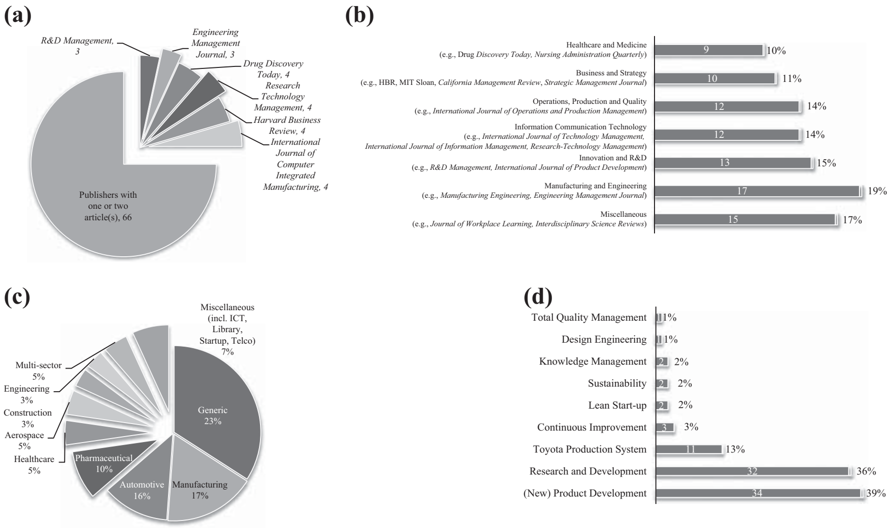
Appendix



Notes: (a) Publishers with ⩾3 articles on Lean and Innovation Management; (b) underlying disciplines of the selected articles; (c) industry sectors involved in the selected articles; (d) main perspectives of the selected articles

Figure A1.
Complementary descriptive representation of data

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Erdogan Gulyaz is Senior Project Manager – New Product Development (NPD), working for a large multinational organization. He worked as Design Engineer, Process Engineer and Project Manager (NPD) over 12 years in various countries for multinational organizations. Following his MBA, he pursued a PhD in "Lean and Competitiveness," which he finished in 2017. Besides, he is Lean Master Trainer and Operations Management Lecturer at Nyenrode Lean Institute. Erdogan has authored several peer-reviewed publications in the area of OM. Erdoğans' areas of interest include Lean management, customer value, new product development and value creation and appropriation.

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