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Lean production myths: an exploratory study

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Abstract

Purpose: this paper presents an exploratory investigation of myths on lean production (LP), by identifying, dispelling, and assessing their pervasiveness.

Design/methodology/approach: a list of myths was proposed mostly based on seminal LP texts and our rich experience from researching, teaching, and consulting in lean journeys. Complexity thinking was adopted as a lens for dispelling the myths, as it challenged generalizations implied in myths. An investigation of the pervasiveness of the myths was conducted, based on a survey with 120 academics and practitioners.

Findings: ten myths were identified and dispelled. Survey's results indicated that belief in lean myths was more common among less experienced practitioners (< 10 years), while experience was not a relevant factor for academics.

Limitations: the lean myths partly reflect the experience of the authors. Furthermore, a larger sample size is necessary for a full analysis of pervasiveness.

Practical implications: the lean myths might be underlying barriers to LP implementation (e.g., lack of knowledge of managers and workers), and they might be proactively accounted for in lean training and education programs.

Originality: this is the first work to explicitly frame a set of lean myths.

Keywords: lean production, myth, complexity thinking.

1. Introduction

Lean production (LP) is an established field of practice and a maturing scientific discipline, as shown by the several literature reviews that have made sense of the growing body of knowledge (e.g. Dorval *et al.* 2019; Sangwa and Sangwan 2018). However, this widespread use of lean has contributed to misunderstandings, which can be exemplified by the various definitions of LP, its core principles, and practices (Antony *et al*. 2020).

In fact, LP is often dogmatic, risking to lead practitioners and researchers alike to accept oversimplified causal links that can overestimate the benefits of lean, while at the same time hindering the exploitation of its full potential. This situation has given rise to myths about LP, which have remained concealed. Myths have been discussed in other areas of operations management, such as Six Sigma (Kumar *et al.* 2008) and quality assurance (Nwankwo 2000). We define a myth as a false or unfounded belief or idea. Therefore, some myths (i.e. those unfounded) may arise from research gaps and thus they may prove not to be myths in face of new evidence and knowledge. The notion of lean myth is ironic given that LP is credited with dispelling myths of traditional management approaches. For example, lean is counter-intuitive in advocating for standardization as a means for obtaining flexibility and overproduction as waste (Liker 2004).

Myths are probably underlying a common problem in lean implementation, namely managers' and workers' lack of understanding of the role played by context (Netland 2016). Pearce *et al.* (2018) found that "the real problem with achieving lean success was not management commitment but their ignorance of what they should commit to, hence a knowledge problem". Similarly, Lodgaard *et al*. (2016) concluded that the nature of misunderstandings varies across hierarchical levels in a company – e.g. managers and workers tend to have different types of misunderstandings. Furthermore, people might have difficulties in learning LP theory, terminology, and benefits. Adam *et al*. (2020) found that to be significantly influenced by the hierarchy of the job and the learner's level of education.

In this article, we draw on our rich experience from researching, teaching, and consulting in lean journeys in a number of firms. Along with support from literature, that experience allowed us to identify recurrent questions and misunderstandings among practitioners, which gave rise to a set of myths described in this paper. We use complexity thinking as a remedy for dispelling lean myths. This perspective is adopted as LP plays out as a complex system, involving a number of principles and practices, which interact between themselves and with the environment (Marksberry 2012). Other studies have also adopted a complexity lens to analyse LP, usually emphasizing the detrimental effects of high environmental complexity (Wang *et al.* 2020; Marley *et al.* 2014), although mixed implications have also been discussed (Soliman *et al.* 2018). In addition, LP has been adopted in sectors with complexity characteristics that differ significantly from car manufacturing. For that reason, a deeper understanding of how LP accounts for complexity is necessary, as to facilitate its application across contexts (Soliman and Saurin 2017).

We also present an analysis of the extent to which lean myths are disseminated among researchers and practitioners. That was based on a survey answered by 120 practitioners and academics. Considering the strong influence of both consultancies and the practitioner oriented-literature, practitioners could be more susceptible to believe in lean myths. The identification of groups more likely to believe in lean myths has implications for the design of educational and training interventions.

2. Complexity thinking: key premises

Complexity thinking is concerned with understanding the interactions between the elements that form a system, instead of only understanding the properties of the elements (Braithwaite *et al.* 2018). Those interactions give rise to emergent phenomena, which have new properties that do not exist in the individual system elements (Cilliers, 2005). This paper is concerned with complex *socio-technical* systems (CSSs), which involve an interactive ensemble between three sub-systems (social, organizational, and technical), subject to influence from the external environment (Hendrick and Kleiner 2000). LP systems are CSSs in this sense. The main attributes of CSSs are fairly consensual, involving (Saurin and Gonzalez 2013; Perrow 1984): a large number of dynamically interacting elements, non-linear interactions, wide diversity of elements, uncertainty, self-organization, and resilience. Due to these attributes, CSSs cannot be fully controlled, and designers and managers can at best influence the system towards a desired state (Hollnagel 2014). Stability in CSSs is obtained not only by reducing variability but also by coping with variability and continuously adjusting performance based on a mix of feedforward and feedback control (Hollnagel 2014).

Practices that are effective in linear systems might not be so in the face of complexity. Thus, if the system is complex, it should be managed as such. Management guidelines for coping with complexity encompass (Righi and Saurin 2015): *(i)* taking advantage of irreducible complexity attributes – e.g. diversity can be a source of innovation; *(ii)* reducing perceived complexity – e.g. through visual management; *(iii)* reducing the unnecessary portion of complexity, which arises from basic sources of waste; and *(iv)* providing slack resources to dampen the effects of variability, which is a core attribute of CSSs.

3. Method

3.1 Identification of lean myths

Literature support relied on a mix of seminal texts on LP, books from researchers or practitioners that had an insider's perspective of the Toyota Production System (TPS), and papers from reputable journals. Although none these sources explicitly mentioned lean myths, they referred to lean principles at a high abstraction level, aiming at generalization. This underspecification opens a breach for diverse interpretations and the rise of myths.

Our experience (Table I) played a role in the identification of myths. That experience offered plenty of opportunities to act in lean education and implementation by interacting with thousands of practitioners and researchers. A lean myth stemmed from recurrent questions and misunderstandings on LP that we have observed over the years. An initial list of myths was independently prepared by the two leading authors, which then exchanged their drafts and submitted them to the critical analysis of the other authors. Several rounds of refining the wording of the myths were conducted, until a consensus was achieved. Based on the similarity of the subjects addressed by the myths, they were grouped into four categories: functioning of lean systems, applicability, social aspects, and impacts. We opted for not defining upront a set of domains of LP implementation and then identifying myths within each domain; this would pose an artificial constraint that could be counterproductive given the novelty of this topic. The myths were described as statements that were at best imprecise and at worst completely false, conveying either a cause-effect relationship or a guideline for the design and implementation of lean systems.

Table I. Authors' experience that contributed to the identification of lean myths

3.2 Investigation of the pervasiveness of lean myths

For an investigation of the pervasiveness of the myths, a survey was carried out with academics and practitioners. The underlying hypothesis was that practitioners would be more likely to believe in lean myths, as a result of their greater reliance on practitioners-oriented literature and commercial consultancies, which could overestimate the applicability and benefits of LP. We first developed a questionnaire that was structured in two main parts, as follows:

(a) Characterization of the respondent, including information related to educational background and experience;

(b) Next, for each myth, respondents were asked to indicate their level of agreement with the statement on a 10-point Likert-style scale. The anchors of the scale were strongly disagree (zero) and strongly agree (ten).

The questionnaire was conceived using the GoogleDocs® platform, and an invitation was sent to respondents through different channels: *(a)* a mailing list used for announcing executive training programs in LP available at the authors' institution – this list had more than 15,000 addresses; *(b)* 1,200 employers' associations of different industrial sectors; *(c)* 26 regional engineering councils; *(d)* posts at Linkedin groups related to lean; and *(e)* individual invitations to international academics who were personal contacts of the authors of this study and that have been prolific in lean research.

Channels *(a)*, *(b)*, and *(c)* were limited to respondents in Brazil. The questionnaires were sent out to respondents directly by the researchers only for *(a)* and *(e)*. For Linkedin, members of the groups had the opportunity to access and answer the survey. For the employers' associations and engineering councils, representatives from these institutions were asked to forward the e-mail message provided by the researchers. Thus, it was not possible to know precisely the number of potential respondents reached out.

A total of 128 questionnaires were received. From these, eight respondents declared no experience with lean either in teaching, consulting or practice. Thus, these were excluded from data analysis. The final sample was comprised of 120 respondents, whose profile is shown in Table II. Responses related to the myths' statements had their Cronbach's alpha values determined. An alpha threshold of 0.6 or higher was used to verify the reliability of the instrument (Meyers *et al.* 2006).

Table II. Sample characteristics (n = 120)

We clustered observations using the agreement level on myths' statements. Ward's hierarchical method was applied to identify the proper number of k clusters (Rencher and Christensen 2012). Then, k-means clustering method was used to rearrange observations into k clusters. An ANOVA (Analysis of Variance) was performed to verify differences in means of the ten myths (clustering variables) calculated using data from each cluster. We then tested for differences between the contents of clusters. We used Pearson's Chi-Squared test with contingency tables and adjusted residuals to check for differences in individuals in clusters regarding their background – i.e. role (academic or practitioner) and experience. Frequencies of respondents' role and experience level were verified across clusters in each set. We considered significant associations with adjusted residual values larger than |1.96| and |2.58|, corresponding a significance level of 0.05 and 0.01, respectively.

4. Results

4.1 Identification of lean myths

4.1.1 Myths on the functioning of lean systems

Four myths associated with the functioning of lean systems were identified. The first is a meta-myth, as it permeates all others. This myth is a consequence of the growing number of lean practices as well as of the ambitious lean intention of influencing all business areas. It also stems from studies indicating the the joint use of several lean practices tends to produce superior outcomes (Valente *et al*. 2020). This wide scope demands synergistic relationships between lean practices, giving rise to myth 1 as follows:

Myth 1: lean production adopts systems thinking, and therefore best outcomes are always obtained when several practices are jointly applied.

Why it is a myth: the second part of myth 1 (after the comma) oversimplifies the nature of interactions in lean systems and thus it neglects trade-offs between lean practices. Myth 1 results from a mechanistic version of systems thinking, which assumes that interactions are stable and controllable. By contrast, complexity thinking postulates that interactions in complex systems cannot be fully controlled and undesired unintended consequences are always a possibility (Dekker 2011). For example, Ferreira and Saurin (2019), based on the analysis of the interactions between kaizen projects in a hospital, concluded that waste might be a normal by-product of kaizen and part of their cost. This is paradoxical given that the lean goal of eliminating waste may also create waste.

Dispelling: lean systems should be modelled and managed as complex socio-technical systems, instead of linear systems (Soliman *et al.* 2018). Thus, there should be acknowledged: the non-linear and not fully controllable nature of the interactions between practices, and between these and the environment; and the context-dependent nature of the most effective combination of lean practices. This combination does not necessarily imply the elimination of trade-offs between lean practices; it rather implies an explicit analysis of trade-offs and the use of explicit criteria for their management.

The second lean myth stems from the TPS principle of growing leaders who "live the philosophy" and teach it to others, fostering an organizational culture in which following the lean principles is the norm (Liker and Hoseus 2008). This principle implicitly assumes that people in a lean system make decisions rationally, have freedom of choice, and can anticipate the long-term and system-wide implications of their decisions. Then, myth 2 is stated as follows:

Myth 2: in a mature lean system, people always follow the lean principles.

Why it is a myth: none of the aforementioned assumptions underlying this myth hold true in light of complexity thinking. First, both in lean and non-lean systems, decision-making on the spot often occurs under time pressure and uncertainty. This means naturalistic decision-making, relying on intuition, tacit knowledge, and influenced by local conditions, without any structured comparison between alternative courses of action (Zsambok 2014). Second, complex systems are inherently uncertain and non-linear, which conveys that no individual or team is cognitively capable of precisely anticipating the long-term and system-wide implications of their actions (Cilliers 2005). Third, acute and chronic efficiency pressures (e.g. for being faster, better, and cheaper) might be strong and part of everyday work (Woods 2006), to the point of being impractical to comply with lean principles all the time.

Dispelling: it should be made clear to people in a lean system that the violation of lean principles can be legitimate and even desirable under certain circumnstances. However, mechanisms should be in place to give visibility to these violations and their rationale, which could be seen as incidents worth investigating and communicating to employees. Gayer *et al.* (2020) describe an example of the violation of a core pull production principle in a manufacturing plant, namely not respecting work-in-process caps and overproducing. In that case, overproduction was a compensation for process instabilities arising from absenteeism in a downstream process. Management decided not to stop upstream production reckoning that only the downstream process would need to work overtime to catch up with the schedule. Otherwise, overtime would be necessary to all processes in the value stream, implying greater costs (Gayer *et al*. 2020).

Similar situations have been seen in how some lean supply chains have coped with the COVID-19 pandemic. For example, the pandemic has challenged the viability of supply chains designed to minimize working capital tied up in assets in warehouses (Wharton University of Pennsylvania 2020). It has also forced many lean organizations to use alternative sources of raw materials from new suppliers (Alicke *et al.* 2020), thus conflicting with the lean principle of long-term customer-supplier relationship (Liker 2004).

The third myth related to the functioning of lean systems sets out that the daily activities of lean leaders emphasize process management rather than focusing on the achievement of desired results. Management by results has two dimensions: acting reactively to correct outcomes that are not as expected; and pursuing the desired outcomes at any cost, even if this means wide deviations from standardized procedures (Drucker 2012). In turn, process management suggests that leaders should closely monitor and influence administrative and production processes that lead to required outcomes (Drucker 2012). LP is an approach for process improvement, and therefore a process orientation makes sense. This emphasis underlies myth 3, which is stated as follows:

Myth 3: if lean leaders emphasize process management, desired results are easily-achieveable consequences.

Why it is a myth: linear thinking underlies myth 3, which assumes clear cause-effect relationships between "right" processes and "right" outcomes. This usually holds true at the micro-level of lean systems (line/cell) – e.g., quality inspection at the source (i.e. at the process generating quality), rather than quality at the end of the line (Ohno 1988). However, the aforementioned statement becomes a myth when expanded to the meso (plant) and macro levels (supply chain). At those levels, there might be a much higher number of non-controllable contextual factors external to the processes. This means that lean leaders might inevitably, and frequently, act reactively and under severe time pressure (Setianto and Haddud 2016), which is a form of managing results instead of processes.

Dispelling: the definition of what counts as a process to be managed should acknowledge that process boundaries are dynamic and open to the environment (Cilliers 2005). Thus, process management should also account for the management of a dynamic context – e.g. anticipation of threats and opportunities. Furthermore, management by results should seek to learn from both desired and undesired outcomes, as the former do not necessarily arise from people following standardized procedures (Hollnagel 2014). Soliman and Saurin (2020) provided evidence of that in a study of an auto-parts manufacturer, in which the positive results of the lean system partly stemmed from the resilience of front-line workers. These devised effective solutions unanticipated and sometimes conflicting with the "right", standardized process, imagined by leaders. Due to that, Soliman and Saurin (2002) coined the terms "lean-as-imagined" (by leaders and standards) and "lean-as-done" (in the real world). Bernstein (2012) reported a similar situation in an assembly line of electronics.

The fourth myth arises from the notion of "lean", which conveys the idea of making more using fewer resources, and little slack, to the point of achieving the elusive zero inventory goal (Shingo 1989). Slack is a mechanism for reducing interdependencies and slowing down or eliminating variability propagation (Safayeni and Purdy 1991). Thus, slack may be formed by resources of any nature (e.g., time, staff, and space) that can be called on in times of need in order to cope with variability (Saurin and Werle 2017). Indeed, just-in-time production is recognized by low inventories, tightly-coupled processes, and the resulting possibility of quick variability propagation – this is seen as positive as it creates a sense of urgency for action-taking (Bhasin 2012). These widely held beliefs, in addition to the common misapplication of lean as a cost-reduction program (Dhingra *et al.* 2019), give rise to the myth as follows:

Myth 4: lean systems have little slack, facilitating variability propagation as to create pressure for corrective actions.

Why it is a myth: this myth misses the point that lean systems have a much wider range of slack resources in addition to inventories. Several slack resources embedded in lean systems might be mentioned, such as: *(i)* help chain, which is a routine for escalating problem-solving when dealing with abnormalities; each level at the help chain acts as a form of redundancy to the lower level (Tortorella and Fettermann 2018); *(ii)* two eight-hour daily shifts with four-hour intervals in-between; this provides capacity slack to cope with production delays and variations in demand besides being useful for equipment maintenance (Monden 2011); *(iii)* a multi-skilled and cross-trained workforce, which means that workers are to some extent redundant to each other (Liker 2004); and *(iv)* decision-making by consensus, which means that diverse perspectives are considered when designing and implementing improvements (Liker 2004); this accounts for cognitive slack (Schulman 1993).

In common, all these slack resources absorb or dampen variability propagation, creating loose-couplings in lean systems. However, differently from inventories, most of them are immaterial, which is a contributing factor to myth 4.

Dispelling: lean textbooks and lean education, in general, should make explicit that, while lean systems seek to control wastes and reduce variability, they also have an arsenal of variability coping mechanisms. The rationale for slack resources should also be made clear: despite all efforts, a significant portion of variability, often unpredictable in terms of timing and intensity, is expected in complex systems. Additionally, complexity thinking suggests that the use of slack resources tends to be more effective after process simplification based on LP (Marley *et al*. 2014). This is counterintuitive since waste removal is commonly interpreted as a signal that slack can be removed as a result of greater process stability. Marley *et al*. (2014) illustrate this point in the study of the role played by slack resources, in terms of inventories, for coping with supply chain disruptions.

4.1.2 Myths on the applicability of lean systems

One myth related to the applicability of lean systems was identified. It stems from the ever growing variety of sectors where lean has been applied, from humanitarian supply chains to higher education, healthcare, construction, manufacturing, and many others. These applications gave rise to myth 5 as follows:

Myth 5: lean practices and principles are equally applicable independently on the sector.

Why it is a myth: this myth overestimates the applicability of lean by neglecting that it is a system comprised of several social-technical elements aimed at internal processes, suppliers, and clients (Shah and Ward 2007). Given this wide scope, it would be surprising if lean systems as a whole were equally applicable independent on the sector. A more realistic claim might be that most lean principles (e.g. waste control) and certain practices (e.g. value stream mapping) are useful within a certain sector (e.g. manufacturing), and under certain contextual conditions (e.g. a workforce capable of applying structured problem-solving methods). A simple example of inapplicability of a lean principle and practice refers to sectors that involve natural systems, like agriculture and animal breeding. In these cases, the pace of production and size of inventories cannot be fully controlled, thus undermining the central tenet of pull production (Barth and Melin 2018).

Dispelling: from an academic standpoint this myth has already been *partly* dispelled by earlier studies that concluded that the essence of the TPS was in high-level and abstract principles, rather than in the observable shop-floor practices adopted by Toyota (Spear and Bowen 1999). However, *partly dispelled* must be emphasized as those studies still claim that the principles are widely applicable, without clearly specifying under which conditions they are not applicable. As such, dispelling of myth 5 might benefit from a systematic analysis of each unique context when designing a lean system, setting a basis for mapping contextual factors onto lean practices and principles.

4.1.3 Myths on the social dimension of lean systems

As for the social dimension of lean systems, two myths have been identified. According to Ohno (1988) “respect for people” was at the core of the TPS. This respect was shown by the nature of the activities carried out by front-line workers, who acquired a broader range of skills, in comparison to the Taylorist model. Workers’ responsibilities in lean systems encompass maintenance of their own equipment, kaizen activities, quality control, and problem-solving, among others (Parker 2003). Workers’ development is a key for lean systems, as improvements ideally should be carried out by those at the front-line of operations, under the coaching of higher ranks (Spear and Bowen 1999). As such, job satisfaction and motivation would be expected to benefit from richer job content and opportunities for self-development. Myth 6, stated below, is an intuitive consequence of this background.

Myth 6: respect for people is a key to lean systems, and therefore job satisfaction and motivation tend to be natural by-products.

Why it is a myth: the notion of respect for people is strongly influenced by Japanese culture, which values collectivism, discipline, and long-term goals (Wittrock 2015). In fact, what counts as “respect for people” differs according to a number of variables not only connected to national culture, but also (e.g.) related to different generations of workers, hierarchical rank, and economic sector. Thus, “respect for people” is a somewhat vague and contingent feature of lean systems. For instance, generation Y or millennials (born between 1980 and mid-1990s) are known for preferring short- to long-term plans (Burch and Smith 2019). Thus, Ys may struggle with the adoption of lean principles set out by Liker (2004), such as “base your management decisions on a long term philosophy, even at the expense of short-term financial goals” and “slowly make decisions through consensus, but rapidly implement them”. Furthermore, several studies (e.g. Drotz and Poksinska 2014; Longoni *et al.* 2013) have pointed out that the impacts of lean on working conditions are mixed, involving both desired (e.g. better housekeeping) and undesired consequences (e.g. greater stress). From our experience as consultants, myth 6 is often a taboo in companies at the earlier stages of the lean journey. In that stage, managers are eager to motivate employees and sell the lean project to them. As a result, managers might be tempted to overemphasize possible gains for employees and silence voices that warn of downsides.

Dispelling: dispelling myth 6 requires an understanding of the need for joint optimization of the socio-technical sub-systems. Therefore, what matters is the compatibility between the workforce’s expectations and characteristics (i.e. social sub-system) and the nature of work relations and job content (i.e. work organization and technical sub-systems). There should be emphasized the role played by lean leadership (Seidel *et al.* 2019), which through example should contribute to the development of a relatively homogeneous organizational culture, facilitating the mentioned compatibility.

Another myth related to the social dimension of lean systems refers to the long-term relationship that companies establish with their employees. In the late 1940s, Toyota was on the brink of bankruptcy and announced layoffs and wage reductions, which led to a two-month strike. As part of the measures to solve this conflict, Toyota provided lifetime job security for the remaining employees (Liker and Hoseus 2008). Toyota became known for heavily investing in people development, expecting payback in the long-term. Of course, such investment would be mostly lost in case of mass dismissals to cope with economic downturns. A superficial understanding of this situation gave rise to myth 7, as follows:

Myth 7: job security is a key to lean systems, which otherwise may not count on a workforce committed to continuous improvement.

Why it is a myth: although job security was an effective solution to Toyota decades ago, more recently it has not been a core TPS element. According to Liker and Hoseus (2008), similarly to competitors, Toyota strongly relies on temporary workers to cope with significant variations in demand. Furthermore, the labor market has been deregulated in many countries, creating the so-called "gig economy" where self-employment and flexible working hours are the norm (Burtch *et al.* 2018). Sancha *et al.* (2019) in a large sample of companies in Europe concluded that temporary workers positively influenced the relationship between lean and mix and volume flexibility performance. Myth 7 is also at odds with the difficulties and failed experiences of implementing lean in the public sector (Radnor and Osborne 2013), which is characterized by job security in many countries. Overall, myth 7 overestimates the role played by job security in successful lean systems.

Dispelling: dispelling myth 7 requires an understanding of contextual conditions that can interact with job security and produce either desired or undesired consequences. On the one hand, low competitiveness pressure is an exemplar contextual factor that, associated with job security, could contribute to complacency. On the other hand, activities that require expertise in complex settings may benefit from a workforce familiar with the context, thus making long-term employment an asset. Another way of dispelling myth 8 is by focusing on turnover reduction, which in the long-term may look similar to job security.

4.1.4 Myths on the impacts of lean systems

Three myths related to the impacts of lean systems are discussed. In comparison to the myths previously described, myths on lean impacts are arguably more related to the way research on lean has been conceived. This is why the dispelling of these myths mostly implies opportunities for further research. In fact, at a cursory view and given the large number of research studies reporting positive impacts of lean on operational performance (e.g. Chavez *et al*. 2013), myth 8 stated below would hardly be questioned.

Myth 8: the superiority of lean production has been proved through highly credible scientific designs and empirical evidence.

Why it is a myth: research designs for the assessment of impacts of lean are fairly limited in terms of variety. Before-after uncontrolled case studies and questionnaire surveys are two ubiquitous approaches (Jasti and Kodali 2015). The former lacks a counterfactual, which could indicate whether the lean intervention, or something else, played the main role in the outcomes. As for the latter, questionnaire surveys are usually based on self-reports, which pose a number of well-known limitations, such as social desirability (i.e. responses that present the respondent in a favourable light), the use of single data sources, responses not verified by independent researchers, and a respondent's tendency to overestimate the strength of the empirical relationships they have observed between classes of events (Podsakoff and Organ, 1986).

Dispelling: there is a need for innovative research designs that shed light on the web of cause-effect relationships involved in lean implementation, also accounting for non-linear interactions between lean practices and contextual factors. The use of counterfactuals could be more explored, both for case studies and when large samples are accounted for. Also, more longitudinal studies would be welcome, as these could offer insight into how and why lean is affected by contextual changes. The hypothesis that these changes (e.g. replacement of leadership), rather than lean, were the main contributing factor to outcomes would be worth investigating. Regarding questionnaire surveys, these could provide additional contribution when combined with qualitative methods, providing triangulation of data and methods – e.g. focus groups to validate findings with representative respondents and experts.

Myth 9 derives from myth 8, being related to the financial impacts of lean systems. Waste reduction as a result of lean implementation is generally associated with higher profitability (Valente *et al*. 2020). Despite possible investments for setting up a lean system (e.g. training, machines improvement, and layout modifications), it is believed to positively impact companies' financial performance, allowing them to thrive in the short and long term (Hines *et al.* 2011). To convey such managerial belief, myth 9 is stated as follows:

Myth 9: lean implementation benefits companies' financial performance, entailing an attractive payback for shareholders.

Why it is a myth: lean initiatives are poorly connected with financial metrics (Netland *et al.* 2015), and they usually do not account for the costs of lean implementation, which may be significant especially for small and medium-sized firms (Valente *et al*. 2020). Furthermore, evidence on the net effect of lean on financial performance is mixed. Some researchers (e.g., Ahmad *et al.* 2004) found that the adoption of core lean practices, such as just-in-time or *jidoka* does not necessarily enhance profitability. In opposition, other studies (e.g., Hofer *et al.* 2012) propose that the assessment of lean should make inferences on financial impacts from non-financial measures. Furthermore, our consultancy experience suggests that myth 9 thrives due to vested interests and the myriad factors that influence financial performance. Top management, which sponsors the lean journey, needs to justify the resources allocated to that. For that reason, good financial performance may be (for external audiences, such as shareholders) conveniently associated with LP, despite unclear cause-effect relationships. Additionally, we observed cases of aggressive cost-cutting promoted by top management on behalf of LP, although critics inside their companies reported concerns with top management earnings of bonuses as a result of short-term financial performance. This situation is compounded by the high turnover of top managers in some companies, as they may not be committed to the company's long-term sustainability.

Dispelling: a possible way of dispelling this myth is by re-interpreting operational metrics from a financial perspective (e.g. setup time, rework) as well as by using financial metrics – which should include the costs introduced by lean, as a standard part of lean assessment studies. Dispelling of myth 9 might also benefit from long-term assessments of financial performance and multidisciplinary research teams, providing diverse perspectives for making sense of complex systems (Page, 2010). Greater involvement of researchers with financial expertise would be welcome.

The last myth comprises lean impact on business' long-term sustainability. LP is argued to address both sources of internal variability and the sources of volatility derived from the uncertainty of the environment; thus, lean companies may thrive and sustain their businesses in the long run (Uhrin *et al* 2020). To refer to this, the following myth is stated:

Myth 10: companies that use lean systems ensure their long-term business sustainability.

Why it is a myth: in face of economic downturns, such as the 2008 recession (Kotz 2009), even companies widely known for their lean systems were forced to downsize and, in more critical cases, to close entire sites. These measures were a response to difficulties such as lower demand and higher tax or labor rates. From a complexity perspective, these cases make clear that the external environment is a permanent source of uncertainty (Dekker 2011), and that the adaptive capacity of lean companies is finite.

Dispelling: further studies could explore how lean systems behave under different conditions of the external environment, evaluating the extent to which lean companies perform differently from non-lean companies. The COVID-19 pandemic offers an opportunity for this type of investigation, as many supply chains have faced unprecedented disruptions (Ivanov and Das 2020). These studies could account for both chronic (e.g. long-term recession) and acute conditions (e.g. strikes). Such investigation would be particularly important for small firms, as these are more vulnerable to global competition and have a higher failure rate than medium and large-sized companies (Signoretti 2020). Findings would shed light on the limits of LP in terms of its adaptability to a changing external environment. A possible by-product of these studies might be a deeper knowledge of the adaptive strategies devised by lean companies as well as the contextual conditions under which they work. This type of study is necessary as LP should go hand-in-hand with resilient practices that protect against severe disruptions (Uhrin *et al*. 2020).

4.2. Pervasiveness of lean myths

Two clusters were identified and set as input ($k = 2$) for k-means clustering method. From this, the 50 observations assigned to cluster 1 presented a lower average agreement level of lean myths and were denoted as ‘Low Agreement cluster’. In turn, the 70 observations assigned to cluster 2 presented a higher average agreement level of lean myths, and were labelled ‘High Agreement cluster’. Results from ANOVA (Table III) indicated that all ten myths’ statements (clustering variables) presented significant differences in means, validating the clusters. This finding conveys that the pervasiveness of lean myths might vary substantially across a given sample.

Table III. ANOVA *post hoc* analysis of clustering using *k*-means method ($k = 2$)

Table IV sheds light on the contingent nature of lean myths. It presents the results from Pearson's Chi-Squared tests for frequencies of respondents' role and experience levels according to each cluster. Findings indicate that, when analysed separately, the agreement level on lean myths is only associated with respondents' experience ($\chi^2 = 4.935$; p-value < 0.05). When respondents have less than 10-year experience on LP, they are more likely to present a higher agreement level with lean myths. However, as experience with LP grows (> 10 years), respondents seem to become more sceptical with lean myths resulting in a higher frequency of respondents in the low agreement cluster.

Table IV. Chi-square test for roles and experience according to myths' agreement levels

When we verify the association between the combination of respondents' role and experience with lean myths' agreement level, new insights arise. Results for Pearson's Chi-Squared test for roles based on experience according to myths' agreement levels, indicated that the perception of academics on lean myths did not significantly vary, regardless their experience level. This means that the occurrence of lean myths might be equally perceived by both low- and high-experienced academics.

By contrast, when we considered practitioners and their experience, a different outcome was found. Low-experienced practitioners were more frequently found in the high agreement cluster, while high-experienced ones were significantly more frequent in the low agreement cluster ($\chi^2 = 6.344$; p-value < 0.05).

5. Discussion

Belief on lean myths may be underlying some barriers to lean implementation, such as managers' lack of technical knowledge and skills, difficulties in seeing the financial benefits, and not sustaining the improvements in the medium and long-term (Marodin and Saurin 2015). For example, wrong implementation approaches (e.g. simultaneously applying a bundle of lean practices – myth 1, without understanding their interactions) may imply waste of resources. Similarly, taking for granted that lean entails positive financial impacts (myth 9) may end up in frustration given that traditional performance indicators may not capture those impacts.

Two general approaches for dispelling lean myths are proposed. From people's development standpoint, there is an opportunity for explicitly addressing lean myths in education and training, through improvements in existing serious games (e.g. Adam *et al*. 2020), textbooks, and curriculum. The dispelling of lean myths through education and training might be more useful in the pre-implementation phase of LP, which is concerned with the identification of barriers, human factor needed, training and knowledge gaps (Antony *et al*. 2020).

People's development is expected to be more important for less experienced practitioners, as suggested by the survey's results. The obtained 10-year cut-off point for obtaining the clusters suggests that it takes a significant time for dispelling lean myths only from experience. However, a long time of practice is unlikely to be a determinant for dispelling the myths and becoming proficient in lean competencies. As it occurs in other fields in which expert performance has been studied (e.g. Hambrick *et al*. 2014) time for acquiring lean expertise may vary substantially. Research on the effectiveness of lean leasdership suggests the same, as it is expected to depend not only on leaders' personal attributes, but also on processes for influencing followers and organizational context (Seidel *et al.* 2020).

From a lean research perspective, there is a need for: *(i)* longitudinal studies, for unveiling how a dynamic context over the long-term interacts with a lean system; Tortorella *et al.* (2020) provides an example of what this type of study could look like in the realm of lean leadership in healthcare; *(ii)* comparisons across industrial sectors, evaluating the extent to which domain-specific lean literature and practice (e.g., lean construction, lean healthcare, lean manufacturing) are convergent or not – and if meaningful generalizations are possible; and *(iii)* the use of counterfactuals that may provide more convincing evidence of whether lean, or something else, plays a key role in outcomes. Furthermore, another dispelling approach worth pursuing concerns the development of new lean implementation methods explicitly considering the myths from the outset.

Complexity thinking might be a theoretical framework for both designing and assessing the impacts of innovative research and educational artefacts devised for coping with the myths. For instance, complexity thinking's concern with unintended consequences suggests that a broad range of outcome measures is necessary for assessing lean interventions. These measures should account for effects not related to the primary focus and object of the intervention, thus allowing the detection of spillovers. It also makes clear the need for long-term assessment of impacts, given that complex systems are always evolving (Soliman and Saurin 2017).

6. Conclusions

This paper has presented an exploratory investigation of ten myths associated with LP functioning, applicability, social dimension, and impacts. By making lean myths explicit, this study sheds light on what might lie beneath an under explored barrier to lean implementation reported by previous studies, namely the lack of knowledge of managers and workers. As revealed by the survey's results, this articulation of lean myths might be useful mostly for less experienced lean practitioners (<10 years). We propose that the dispelling of lean myths should rely on both people's development and research initiatives, guided by complexity thinking. This theoretical perspective acknowledges the context-dependent and systemic nature of LP, challenging generalizations and linear cause-effect mechanisms implied in lean myths.

Limitations of this study must be mentioned. Firstly, the sample of survey's respondents was restricted in both geographical and quantitative aspects. In spite of this, the survey structure and the corresponding analytical procedures set a basis for further studies with larger samples. Secondly, the list of lean myths is not exhaustive, besides being partly based on the authors' experience. Therefore, we cannot affirm that the proposed myths are the most widespread that lead to problems with LP implementation in practice.

Lastly, opportunities for further studies might be presented, such as:

(i) To investigate possible myths emerging from recent developments, such as industry 4.0;

(ii) To investigate the influence of other variables related to respondents background (in addition to academic/practitioner and experience) on the belief on lean myths;

(iii) To explore correlations between the level of agreement of leaders with the myths and performance outcomes, the hypothesis being that the greater the agreement with the myths the worse the outcomes;

(iv) To pursue the proposed approaches for coping with the lean myths in education and research. For example, lean myths could be incorporated into serious games and be used as a basis for peer learning, where students exchange ideas on the myth and its implications; and

(v) To develop tools for mapping the context of companies onto what lean can offer. This arises from the finding that a commonality to several myths is that they do not take into account the contingent nature of lean.

References

Adam, M., Hofbauer, M. and Stehling, M. (2020), "Effectiveness of a lean simulation training: challenges, measures and recommendations", *Production Planning and Control*, DOI: 10.1080/09537287.2020.1742375

Ahmad, A., Mehra, S. and Pletcher, M. (2004). "The perceived impact of JIT implementation on firms' financial/growth performance", *Journal of Manufacturing Technology Management* Vol. 15 N. 2, pp. 118–130.

Alicke, K, A. and Barriball, E. (2020). Supply-chain recovery in coronavirus times — plan for now and the future. McKinsey & Company, 18.

Antony, J., Psomas, E., Garza-Reyes, J.A. and Hines, P. (2020). "Practical implications and future research agenda of lean manufacturing: a systematic literature review", *Production Planning & Control*, DOI: 10.1080/09537287.2020.1776410.

Barth, H. and Melin, M. (2018). "A green lean approach to global competition and climate change in the agricultural sector – A Swedish case study", *Journal of Cleaner Production,* Vol. 204, pp. 183–192.

Bernstein E., S. (2012). "The transparency paradox: A role for privacy in organizational learning and operational control". *Administrative Science Quarterly,* Vol. 57 N. 2, pp. 181-216.

Bhasin, S. (2012). "An appropriate change strategy for lean success", *Management Decision,* Vol. 50 N. 3, pp. 439–458.

Braithwaite, J., Churruca, K., Long, J., Ellis, L. and Herkes, J. (2018). "When complexity science meets implementation science: a theoretical and empirical analysis of systems change" *BMC Medicine,* Vol. 16 N.63, DOI: 10.1186/s12916-018-1057-z.

Burch, V., Reuben F. and Smith, B. (2019). "Using simulation to teach lean methodologies and the benefits for millennials", *Total Quality Management and Business Excellence,* Vol. 30 N. 3–4, pp. 320–334.

Burtch, G., Carnahan, S. and Greenwood, B. (2018). "Can you gig it? An empirical examination of the gig economy and entrepreneurial activity", *Management Science,* Vol. 64 N. 12, pp. 5497–5520.

Chavez R, Gimenez C, Fynes B, Wiengarten F, and Yu W. (2013). "Internal lean practices and operational performance". *International Journal of Operations and Production Management,* Vol. 33 N.5, pp. 562-588.

Cilliers, P. (2005). "Complexity, deconstruction and relativism", *Theory, Culture and Society,* Vol. 22 N. 5, pp. 255–267.

Dekker, S. (2011). *Drift into Failure: from hunting broken components to understanding complex systems*. CRC Press, Boca Raton.

Dhingra, A. K., Kumar, S. and Singh, B. (2019). "Cost reduction and quality improvement through lean-kaizen concept using value stream map in Indian manufacturing Firms", *International Journal of System Assurance Engineering and Management,* Vol. 10 N. 4), pp. 792–800.

Dorval, M., Jobin, M. and Benomar, N. (2019). "Lean culture: a comprehensive systematic literature review", *International Journal of Productivity and Performance Management,* Vol. 68 N. 5, pp. 920–937.

Drotz, E. and Poksinska, B. (2014). “Lean in healthcare from employees’ perspectives”, *Journal of Health Organization and Management,* Vol. 28 N. 2, pp. 177–195.

Drucker, P. (2012). *The Practice of Management,* Routledge, London.

Ferreira, D. and Saurin, T.A. (2019). “A complexity theory perspective of kaizen: a study in healthcare”, *Production Planning and Control,* Vol. 30 N. 16, pp. 1337–1353.

Gayer, B. D., Saurin, T.A. and Wachs, P. (2020). “A method for assessing pull production systems: a study of manufacturing, healthcare, and construction”, *Production Planning and Control*. DOI: 10.1080/09537287.2020.1784484.

Hambrick, D., Oswald, F., Altmann, E., Meinz, E., Gobet, F. and Campitelli, G. (2014). “Deliberate practice: is that all it takes to become an expert?” *Intelligence,* Vol. 45, pp. 34-45.

Hendrick, H., Kleiner, B. (2000). *Macroergonomics : an introduction to work system design*. Human Factors & Ergonomics Society, Santa Monica.

Hines, P., Found, P., Griffiths, G. and Harrison, R. (2011). *Staying Lean: thriving, not just surviving,* Productivity Press, Boca Raton.

Hofer, C., Eroglu, C. and Hofer, A. (2012). “The effect of lean production on financial performance: the mediating role of inventory leanness”, *International Journal of Production Economics,* Vol. 138 N. 2, pp. 242–253.

Hollnagel, E. (2014). *Safety-I and Safety–II: the past and future of safety management*. 1st ed. Farnham: Ashgate Publishing.

Ivanov, D. and Das, A. (2020). "Coronavirus (COVID-19/SARS-CoV-2) and supply chain resilience: a research note", *International Journal of Integrated Supply Management*, Vol. 13 N. 1, pp. 90-102.

Jasti, N. and Kodali, R. (2015). "Lean production: literature review and trends", *International Journal of Production Research,* Vol. 53 N. 3, pp. 867–885.

Kotz, D. (2009). "The financial and economic crisis of 2008: a systemic crisis of neoliberal capitalism", *Review of Radical Political Economics,* Vol. 41 N. 3, pp. 305–317.

Kumar, M., Antony, J., Madu, C., Montgomery, D. and Park, S. (2008). "Common myths of six sigma demystified" *International Journal of Quality and Reliability Management,* Vol. 25 N. 8, pp. 878–895.

Liker, J. and Hoseus, M. (2008). *Toyota Culture: the heart and soul of the Toyota Way.* McGraw-Hill Education, New York.

Liker, J. (2004). *The Toyota Way: 14 management principles from the world's greatest manufacturer*. McGraw-Hill Education, New York.

Lodgaard, E., Ingvaldsen, J., Gamme, I. and Aschehoug, S. (2016). "Barriers to lean implementation: perceptions of top managers, middle managers and workers", *Procedia CIRP,* Vol. 57, pp. 595–600.

Longoni, A., Pagell, M., Johnston, D. and Veltri, A. (2013). "When does lean hurt? – An exploration of lean practices and worker health and safety outcomes", *International Journal of Production Research,* Vol. 51 N. 11, pp. 3300–3320.

Marley, K., Ward, P. and Hill, J. (2014). "Mitigating supply chain disruptions – a normal accident perspective", *Supply Chain Management: An International Journal,* Vol. 19 N. 2, pp. 142 - 152.

Marksberry, P. (2012). *The Modern Theory of the Toyota Production System: a systems inquiry of the world's most emulated and profitable management system*. Productivity Press, Boca Raton.

Marodin, G. and Saurin, T.A. (2015). "Managing barriers to lean production implementation: context matters", *International Journal of Production Research,* Vol. 53 N. 13, pp. 3947–3962.

Meyers, L., Gamst, G. and Guarino, A. (2006). *Applied multivariate research: design and interpretation*. SAGE Publications, Thousand Oaks.

Monden, Y. (2011). *Toyota Production System: an integrated approach to just-in-time*. 4th ed. Productivity Press, Boca Raton.

Netland, T. H. (2016). "Critical success factors for implementing lean production: the effect of contingencies", *International Journal of Production Research,* Vol. 54 N. 8, pp. 2433–2448.

Netland, T. H., Schloetzer, J. and Ferdows, K. (2015). "Implementing corporate lean programs: the Effect of management control practices", *Journal of Operations Management*, Vol. 36 N. 1, pp. 90–102.

Nwankwo, S. (2000). "Quality assurance in small business organisations: myths and realities", *International Journal of Quality & Reliability Management,* Vol. 17 N. 1, pp. 82–99.

Ohno, T. (1988). *The Toyota Production System: beyond large-scale production*. Productivity Press, Boca Raton.

Page, S. (2010). *Diversity and Complexity*. Princeton University Press, Princeton.

Parker, S. (2003). "Longitudinal effects of lean production on employee outcomes and the mediating role of work characteristics", *Journal of Applied Psychology,* Vol. 88 N. 4, pp. 620–634.

Pearce, A., Pons, D. and Neitzert, T. (2018). "Implementing lean: outcomes from SME case studies", *Operations Research Perspectives,* Vol. 5, pp. 94–104.

Perrow, C. (1984). *Normal Accidents: living with high-risk technologies*. Princeton University Press, Princeton.

Podsakoff, P.M, and Organ, D.W. (1986). "Self-reports in organizational research: Problems and prospects". *Journal of Management,* Vol. 12 N.4, pp. 531-44.

Radnor, Z., and Osborne, S. (2013). "Lean: a failed theory for public services?" *Public Management Review,* Vol 15, pp. 265–287.

Rencher, A. and Christensen, W. (2012). *Methods of Multivariate Analysis*. Wiley, New York.

Righi, A. and Saurin, T.A. (2015). "Complex socio-technical systems: characterization and management guidelines", *Applied Ergonomics,* Vol. 50, pp. 19–30.

Safayeni, F. and Purdy, L. (1991). "A behavioral case study of just-in-time implementation", *Journal of Operations Management,* Vol. 10 N. 2, pp. 213–228.

Sancha, C., Wiengarten, F., Longoni, A. and Pagell, M. (2019). "The moderating role of temporary work on the performance of lean manufacturing systems", *International Journal of Production Research*, Vol. 58 N. 14, pp. 4285-4305.

Sangwa, N. R. and Sangwan, K. (2018). "Leanness assessment of organizational performance: a systematic literature review." *Journal of Manufacturing Technology Management,* Vol. 29 N. 5, pp. 768–788.

Saurin, T. A. and Gonzalez, S. (2013). "Assessing the compatibility of the management of standardized procedures with the complexity of a sociotechnical system: case study of a control room in an oil refinery", *Applied Ergonomics,* Vol. 44 N. 5, pp. 811–823.

Saurin, T.A. and Werle, N. (2017). "A framework for the analysis of slack in socio-technical systems", *Reliability Engineering and System Safety,* Vol. 167, pp. 439–451.

Shah, R., and Ward, P. (2007). "Defining and developing measures of lean production", *Journal of Operations Management,* Vol. 25, pp. 785–805.

Schulman, P. (1993). "The negotiated order of organizational reliability." *Administration and Society,* Vol. 25 N. 3, pp. 353–372.

Seidel, A., Saurin, T.A.. Tortorella, G. and Marodin. G. (2019). "How can general leadership theories help to expand the knowledge of lean leadership?" *Production Planning and Control,* Vol. 30 N. 16, pp. 1322–1336.

Setianto, P. and Haddud, A. (2016). "A maturity assessment of lean development practices in manufacturing industry", *International Journal of Advanced Operations Management,* Vol. 8 N. 4, pp. 294-322.

Shingo, S. (1989). *A Study of the Toyota Production System from an Industrial Engineering Viewpoint*. Productivity Press, New York.

Signoretti A. (2020). "Overcoming the barriers to the implementation of more efficient productive strategies in small enterprises". *Employee Relations: The International Journal*, Vol. 42 N.1, pp. 149-165.

Soliman, M., and Saurin, T.A. (2020). "Lean-as-imagined differs from lean-as-done: the influence of complexity". *Production Planning and Control*, in press.

Soliman, M. and Saurin, T.A. (2017). "Lean production in complex socio-technical systems: a systematic literature review." *Journal of Manufacturing Systems,* Vol. 45, pp. 135–148.

Soliman, M., Saurin, T.A., and Anzanello, M. (2018). "The impacts of lean production on the complexity of socio-technical systems" *International Journal of Production Economics,* Vol. 197, pp. 342–357.

Spear, S. and Bowen, K. (1999). "Decoding the DNA of the Toyota Production System." *Harvard Business Review,* Vol. 77 N. 5, pp. 96–106.

Tortorella, G., van Dun, D. H. and de Almeida, A. G. (2020). "Leadership behaviors during lean healthcare implementation: a review and longitudinal study", *Journal of Manufacturing Technology Management,* Vol. 31 N.1, pp. 193-215.

Tortorella, G. and Fettermann, D. (2018). "Help chain in companies undergoing a lean implementation." *International Journal of Lean Six Sigma,* Vol. 9 N. 1, pp. 113–132.

Uhrin, Á., Moyano-Fuentes, J. and Cámara, S. (2020). "Firm risk and self-reference on past performance as main drivers of lean production implementation". *Journal of Manufacturing Technology Management,* Vol. 31 N. 3, pp. 458-478.

Valente, C. M., Sousa, P. S. A., and Moreira, M. R. A. (2020). "Assessment of the Lean effect on business performance: the case of manufacturing SMEs". *Journal of Manufacturing Technology Management,* Vol. 31 N. 3, pp. 501-523.

Wang, X., Lin, Y. and Shi, Y. (2020). "The moderating role of organizational environments on the relationship between inventory leanness and venture survival in Chinese manufacturing", *Journal of Manufacturing Technology Management,* Vol. 31 N. 2, pp. 413-440.

Wharton University of Pennsylvania. (2020). *Coronavirus and supply chain disruption: what firms can learn*. Available at: https://knowledge.wharton.upenn.edu/article/veeraraghavan-supply-chain/ (accessed on July 1st 2020).

Wittrock, C. (2015). "Reembedding lean: the Japanese cultural and religious context of a world changing management concept", *International Journal of Sociology,* Vol. 45 N. 2, pp. 95–111.

Woods, D. (2006). "Essential characteristics of resilience", Hollnagel, E., Woods, D. and Leveson, D. (Eds.), *Resilience Engineering: concepts and precepts*, CRC Press, Boca Raton, pp. 22–33..

Zsambok, C. (2014). "Naturalistic decision making: where are we now?", Zsambok, C. and Klein, G. (Eds.), *Naturalistic Decision Making*, Psychology Press, New York, pp. 23–36.

Table I. Authors' experience that contributed to the identification of lean myths

Authors	Lean research	Lean teaching at graduate and executive courses	Lean consultant	Lean practitioner
TAS	16 years, including the supervision of 5 PhD and 26 MSc projects on lean. H-index Scopus = 22	Around 1,500 hours over 16 years	Several projects at companies from manufacturing, healthcare, and construction	None
GLT	16 years, including the supervision of 3 PhD and 8 MSc projects on lean. H-index Scopus = 17	Around 1,500 hours over 16 years	Several projects at companies from manufacturing and healthcare	Twelve years in a large auto parts company playing key leadership roles, such as continuous improvement (CI) coordinator, industrial Manager and regional CI Manager
MS	5 years, including a 9-month in-depth case study in a large auto parts manufacturer to understand the gap between the formal and the actual lean system. H-index Scopus = 4	Around 300 hours over 4 years	Several projects at companies from manufacturing and healthcare	One year in a process office from a large public organization, leading several improvement projects using lean approaches
JAGR	15 years, including the supervision of 2 PhD and 25 MSc projects on lean. H-index Scopus= 24	Around 1,500 hours over 11 years	Several projects in manufacturing, healthcare and service companies	Seven years in the food, electronic, and plastic industry

Table II. Sample characteristics (n = 120)

Role			Experience		
Academic	52	43.3%	< 10 years	74	61.7%
Practitioner	68	56.7%	≥ 10 years	46	38.3%
Academic degree					
Undergraduate in course	5	4.2%	MSc	26	21.7%
Graduated	48	40.0%	PhD	41	34.2%
Country					
Brazil	96	80.0%	Portugal	2	1.7%
USA	5	4.2%	Spain	2	1.7%
Mexico	3	2.5%	UK	2	1.7%
Italy	2	1.7%	Others	8	6.5%

Table III. ANOVA *post hoc* analysis of clustering using k-means method (k = 2)

Myth	Low Agreement (n_1 = 50) Mean	Low Agreement (n_1 = 50) Std. dev.	High Agreement (n_2 = 70) Mean	High Agreement (n_2 = 70) Std. dev.	ANOVA F-value
(1) Lean production adopts systems thinking, and therefore best outcomes are always obtained when several practices are jointly applied	7.44	2.36	8.84	1.64	14.55**
(2) In a mature lean system, people always follow the lean principles.	6.08	2.99	7.84	2.46	12.25**
(3) If lean leaders emphasize process management, desired results are easily-achievable consequence.	5.84	2.56	8.59	2.07	41.20**
(4) Lean systems have little slack, facilitating quick variability propagation as to create pressure for corrective actions.	5.28	3.21	8.57	1.98	47.12**
(5) Lean practices and principles are equally applicable independently on the sector	4.08	3.17	8.20	2.40	64.42**
(6) Respect for people is a key to lean systems, and therefore job satisfaction and motivation tend to be natural by-products.	5.44	3.10	8.76	1.95	50.82**
(7) Job security is a key to successful lean systems, which otherwise may not count on a workforce highly committed to continuous improvement.	5.74	2.86	8.39	2.31	30.88**
(8) The superiority of lean production has been proved through highly credible scientific designs and empirical evidence.	5.64	2.81	8.57	1.82	47.35**
(9) Lean implementation benefits companies' financial performance, entailing an attractive payback for shareholders.	7.50	2.65	9.46	1.27	28.42**
(10) Companies that implement lean systems ensure their long-term business sustainability.	5.50	2.70	8.91	1.62	73.22**

Note: ** p-value < 0.01

Table IV. Chi-square test for roles and experience according to myths' agreement levels

Respondents characteristics		Low Agreement		High Agreement		Total frequency	Pearson's chi-square
		Frequency	**Adjusted residual**	**Frequency**	**Adjusted residual**		
Role	Academics	24	0.9	28	-0.9	52	0.760
	Practitioners	26	-0.9	42	0.9	68	
Total frequency		50		70		120	
Experience	< 10 years	25	-2.2	49	2.2	74	4.935^{*}
	≥ 10 years	25	2.2	21	-2.2	46	
Total frequency		50		70		120	

Note: * *p*-value < 0.05.