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A new Lean Six Sigma framework for improving competitiveness

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ABSTRACT:

Manufacturing companies strive for ever-increasing competitiveness through productivity and quality. This goal can be achieved through the implementation of lean manufacturing and six sigma methodologies. Lean manufacturing adds value by reducing waste, while six sigma eliminates variability. In this context, this article proposes a new framework within Lean Six Sigma circumstances. The framework was proposed by means of an exhaustive literature review which identified the positive points of other Lean Six Sigma frameworks available on literature. The framework was applied to a case study, and the assessments were based on semi-structured questionnaires and analysis of records and documents. The implementation was carried out in a manufacturing company in Brazil, which belongs to an American-based multinational. In the case study described herein, the manufacturing company established the proposed framework to support the combination of lean manufacturing and six sigma and introduced an enterprise-wide culture of project through the proposed Lean Six Sigma framework, which resulted in significant benefits.

KEYWORDS: Lean Six Sigma, improvement, competitiveness, productivity.

INTRODUCTION

The challenge of manufacturing management to introduce innovations in the manufacture of products entails not only the design and implementation of new methods but also organizational changes and the involvement of human resources (Thürer, Godinho Filho, Stevenson, & Fredendall, 2015). A key to innovation is the application of methodologies aimed at improving manufacturing, as well as processes such as lean manufacturing focusses on reduction of lead time and six sigma a well-established approach that looking for eliminate defects, which complement each other as Lean Six Sigma (LSS) (Godinho Filho & Utiyama, 2016). The combination of LSS is beneficial because it compensates for limitations in their components (Shokri, Shirley, & Nabhani, 2016). In addition, it is important for practitioners to be aware of LSS implementation processes, in view of limitations and impeding characteristics such as motivation (Albliwi, Antony, & Lim, 2015; Freitas & Costa, 2017).

The present study was motivated by the industry's need for a framework that enables an organization to select project portfolios aligned with the manufacturing company's strategic planning, and after

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implementation, monitor them for one year via financial indicators. Thus, the quest for competitiveness addressed by the study can be expressed in the following research question: Can Lean Six Sigma be proposed in a new way to achieve greater competitiveness? To answer this question, a new LSS framework and a case study was undertaken to develop a proposed guide that combines lean manufacturing (LM) and six sigma (SS). This combination, LM and SS, also highlights the lack of an LSS framework in the literature, which establishes application of a functional structure that simultaneously manages: the manufacturing and engineering area in the implementation of continuous improvement programs through lessons learned; elaborates risk and attractiveness analyses when selecting projects; uses process mapping combining with plan-do-check-act. The framework proposed in this paper aims at filling this gap.

MATERIAL AND METHODS

Research methodology in this study can be divided into four stages (Table 1).

TABLE 1.
Research methodology.

Stage 1: definition of the problem and the research objective
The factors reported in the study were motivated by the challenge of creating a new LSS framework to guide a Brazilian manufacturing company to improve its competitiveness. The orientation used to implement LSS is described (Assarind & Aaboen, 2014), and other LSS guides proposed for industry can be found in the implementation represented in a simplified plan-do-check-act (Chaurasia, Garg, & Agarwal, 2016). To reconcile this situation, this study proposes a new LSS framework to facilitate the manufacturing's involving stakeholders and tracking LSS implementation outcomes.
Stage 2: systematic review
i) year: a systematic review of the literature from 2008 to 2016 was made, regarding LSS concepts used in LM and SS implementation and their characteristics; ii) databases: it was conducted, using the ISI Web of Knowledge, Scopus, Compendex, and Google Scholar; iii) initial screening: it was used the keyword 'lean six sigma', and engineering, only articles were selected (excluding seminars, conferences), it was found 310 articles; iv) refinement: the results were further refined, using the keywords 'framework' and 'improvement', it was found 137 articles; v) aspects: after the redundancies were eliminated, the remaining articles were reviewed using characteristics (motivation, mapping, risk analysis, portfolio, lessons learned) of each studied (it was selected 41 articles); vi) framework: a new LSS framework was crafted from the positive aspects of each studied reference proposed (final selection: 18 articles). The articles were selected, encompassing, firstly, the manufacturing area, were also considered articles of general applications, as an example of the author Snee (2010) and an application in services, by the author Chaurasia et al. (2016).
Stage 3: Lean Six Sigma framework proposal and application
The proposed LSS framework was applied in the case study in a Brazilian manufacturing company. The case study is an empirical way to examine a contemporary phenomenon in a real-life context. This is particularly useful when the boundaries between phenomenon and context are unclear. i) study period: the case study collected data taking care of the cause and effect relationships of the last two years; ii) protocol: the research protocol was elaborated according to the interview script, which was agreed with the questions and procedures of conducting research, providing validity and reliability. It also included the implementation of the LSS and its characteristics (motivation, mapping, leadership); iii) conduction: a pilot test was prepared with the senior executive; iv) data collection: in this study, it used the semi-structures questionnaire allowing free response, interviews, and project records; v) quality criteria: the quality criteria considered validity: internal, external and construct. The internal validity represented the level of confidence regarding the cause and effect of the variables, verifying the evidence. The external validity evaluated the generalization of the conclusions, if they can be applied in different areas. The validity of the construct verified the degree of extension generated by the observations, which represent the measured characteristics, their variables and limitations; vi) replication: elaborate the literature review identifying gaps and research question. Prepare protocol and select data taking into account the necessary and sufficient conditions. Plan the study considering the types of validity, which relate to the characteristics of the research. Describe the case with critical quality analysis. Conduct the research considering only evidence related to the data (Yin, 2003).
Stage 4: discussions and conclusions
This stage provides and considers the study's findings, limitations, concluding with a proposal for future research to examine the applicability of Lean Six Sigma's implementation in different segments of companies. These four stages of the present study are shown in the following sections.

Basic theoretical aspects of literature

Lean manufacturing (LM) gained prominence in the 1980s as the result of a research project by the Massachusetts Institute of Technology, which studied practices adopted by leading companies in the

automotive supply industry and found that the following LM practices significantly contributed to increased competitiveness (Bhamu & Sangwan, 2014). The Lean principles are (Womack & Jones, 2003; Snee, 2010): (i) identify value; (ii) measure the value; (iii) pull on customer demand; (iv) create value; (v) achieve perfection. For identify and measure the value, LM uses value stream mapping (VSM) to depict the entire process on a single page. VSM enables visualization of the transmission of information from the client to the plant and the flow of material in the process and thus facilitates to add value, and the discovery and eliminate of waste (Table 2).

By eliminating waste, the LM method has been found to reduce costs and the time between client request and delivery through identified via VSM. Tools have been described to reduce or eliminate waste (Table 3).

Six sigma (SS) initiated in the 1980s to increase manufacturing quality in the industry from 3σ to 6σ (zero defects), using statistical tools and process mapping. By understanding customer needs, the vision process, and project implementation, the SS method seeks to improve processes, reducing variation/s that generate defects, through a sequence Deming's plan-do-check-act called Dmaic (Define, Measure, Analyze, Improve, Control) (Albliwi et al., 2015). Development management is receiving increasing attention in the manufacturing sector, from reactive design to predictive design quality. In this context, General Electric developed Dmadv (Define, Measure, Analyze, Design, Verify) cycle an extension of SS called design for six sigma (DFSS) for the development of new projects, wich reduces the number of design changes (projects that don't break in the beginning) (Watson & Deyong, 2010).

TABLE 2.
LM waste (Rother & Shook, 2013).

Waste	Description
over-processing	use of inappropriate procedures
over-production	more products than customer demands
inventory	excess of raw material
defects	inferior products, no right first time and beginning
transportation	excessive movement of people or parts between work positions
motion	disorganization, unnecessary movement within processes
waiting	extensive periods of non-production, parts waiting availability

TABLE 3.
LM tools (adapted from Godinho Filho & Barco, 2015).

Tools	Description
5S	<i>seiri</i> (sort), <i>seiton</i> (straighten), <i>seiso</i> (shine), <i>seiketsu</i> (standardize), <i>shitsuke</i> (sustain) motivate change and establish discipline within the enterprise
PY	<i>Poka-Yoke</i> is any mechanism that helps an equipment operator to avoid errors
JIT	Just-In-Time manufacturing provides greater flexibility
CFM	Continuous Flow Manufacturing promotes one-piece flow by searching the organization of the value stream so the material can be moved quickly from one process to another
SW	Standardized Work uses the most effective combination of operating processes to ensure an activity is performed
SMED	Single-Minute Exchange of Die rationalizes the techniques of quick change
TPM	Total Productive Maintenance improves efficiency in the use of equipment with emphasis on its availability

Lean Six Sigma was defined: 'a business strategy and methodology that increases process performance resulting in enhanced customer satisfaction and improved bottom line results' (Snee, 2010). Lean manufacturing (LM) lacks a structured means to eliminate production variability, while six sigma (SS) does not focus on production time (Albliwi et al., 2015). Combining the best qualities of each method compensates for such shortcomings as follows. Accordingly, some enterprises that had adopted LM or SS-driven methodologies have elected to use both (Snee, 2010). Other adopters of LM or SS have sought to enhance their methodologies by incorporating elements of the other (Pacheco, Pergher, Vaccaro, & Jung, 2015). Such combination, LM and SS, known as LSS, may yield better results than the use of two parallel methods independently (Nicoletti, 2013).

Nowadays companies are paying increased attention to updating management processes. LSS approach has attracted perception from those who have yet to use LM and SS jointly (Assarlind & Aaboen, 2014). Applying the framework to projects serves to structure the research base according to the applicability of LSS.

Systematic literature review

In the systematic review of the literature performed in the present work we found papers that provide frameworks and characteristics for LSS. However, none of them, at the same time, presented a functional structure that manages projects in manufacturing and engineering, elaborates risk analysis, selects projects in line with manufacturing strategic planning, implements VSM combining Dmaic or Dmadv, monitors the return on investment for a year, disseminates lessons learned.

Today's industries require minimum cost by reducing waste and variations, LSS strategies with a VSM and Dmaic cycle could meet this demand, while enhancing business competitiveness (Chaurasia et al., 2016). A decision support system that used portfolio selection to ensure that projects prioritized the required characteristics of the proposed LSS framework arising from research-elaborated alignment with the strategic planning is presented in (Hu, Wang, Fetch, & Bidanda, 2008).

The substantive processes of LSS are critical factors in its success (Jeyaraman & Teo, 2010) in guiding manufactures striving to attain competitiveness (Okhovat, Ariffin, Nehzati, & Hosseini, 2012). LSS provides an outline of how to combine LM and SS to gain valuable insights for CEOs who wish to structure their enterprises more efficiently (Assarlind, Gremyr, & Bäckman, 2013). Integrating VSM and DMAIC will reduce defects by eliminating manufacturing activities that do not add value (Swarnakar & Vinodh, 2016). LSS concepts can enhance the communications process and provide a problem-solving structure for improving ongoing projects (Barnes & Walker, 2010). LSS could integrate Dmaic and DFSS methodologies with lean concepts to better quality and increase productivity and Lean Six Sigma projects focus human behavior in changing processes to achieve excellence (Montgomery, 2010). Its lessons-learned process offers a perspective for organizational improvement efforts (Näslund, 2008). Dmaic and Dmadv methodologies are effective improvement tools, respectively (Sokovic, Pavletic, & Pipan, 2010). The LSS methodology concerns how to select black belt staff to motivate and direct teams (Hilton & Sohal, 2012). This is the LSS characteristics initially found through observations of the first authors studied.

One of the papers does not present a framework, but purposes to explore the most characteristics within LSS; and it describes that the issues that have emerged from this study include benefits, motivation, and limitations, factors providing opportunities for LSS researchers (Snee, 2010). Another paper presents the combination of LM and SS through a framework that describes the Dmaic cycle step by step, but does not emphasize VSM (Vinodh, Gauthan, & Anesh, 2011). There is a paper that describes deficiencies in overcoming lean anchorage within the Dmaic sequence, using training (Gnanaraj, Devadasan, Muruges, & Sreenivasa, 2012). There is also a paper that establishes process information, and current and future VSM states to serve as a guide in developing an action plan (Chen, Li, & Shady, 2010).

The proposed Lean Six Sigma framework

The Lean Six Sigma framework was involved in four phases and ten steps (Figure 1). The framework was applied into project in a Brazilian manufacturing company.

Phase 1 (Establish organization): in the proposed LSS framework the initial phase is to select key personnel, including the black belt, who must be a leader with extensive experience in working on projects, capable of motivating staff to participate actively in changing organizational culture (Table 4).

Phase 2 (Select projects): This phase is composed by a sequence of: portfolio analysis (Table 5); select projects; define scope, time, and cost; maximize staff efficiency by multi-task assignments to LSS staff; analyze attractiveness versus risk (Table 6).

Phase 3 (Implement projects): the third phase is the first activity of the implementation that consists in assessing the current status of the process and determining whether it is the most critical one to meet the needs and expectations of the organization’s stakeholders. From this starting point, the priorities are set, and decisions are made about which areas of the business are to be addressed, and which techniques are the most suitable ones for this phase. In addition, to ensure that the resulting improvement is maintained, the process must be stabilized, confirming its financial result for an one-year period (Table 7).

Phase 4: Monitor projects: this phase monitors the indicators and disseminates the results to other business units (Table 8).

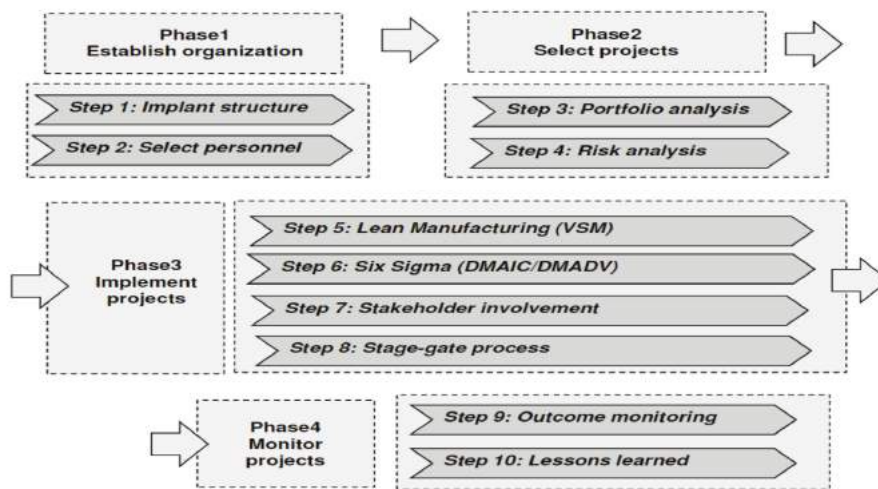


FIGURE 1.
The LSS framework proposed.

TABLE 4.
Phase 1 (Establish organization).

Implant structure: this step concerns a sequence of structure creation; to advance Lean Six Sigma' success, the enterprise established functional structure. In most manufacturing companies, LM is managed on the shop floor and SS in quality engineering. The present study proposes that both be managed by the vice-president of quality, meaning that engineers can talk to operators directly at their workplace, and operators can participate in engineering project teams. The present framework proposes that both be managed in the quality area, it means engineers and operators will work as team. A committed organizational structure is essential to manage teams, through change management, so that the appropriate methodology for each solution can be chosen, be it Lean Six Sigma in improvement. This choice will enable the organization to simplify its manufacturing or administrative processes, resulting in competitiveness.

Select personnel: this step describes a sequence of training and involvement of human resources: encourage innovation; visionary leadership; employee empowerment; be flexible in delivery; ensure quality; seek lowest price. The black belt must develop at least two high-impact projects saving approximately \$300,000 each annually and dedicate resources structure on full-time; they are elected by board of directors. Plans are developed through strategy. Another key staff designation is the green belt, who acts in this role on a part-time basis, while fulfilling present duties. The individual selected as green belt must gain about \$30,000 in new projects each year. This step of selecting staff considers assurance of qualified leadership and the development of an employee-training plan. The recognition and reward of leaders is also very important.

TABLE 5.
Phase 2 (Select projects).

Portfolio: the selection of portfolio-projects analysis should be aligned with business strategic plan which entails the following seven tasks: i) receipt of suggestions by black belt; ii) filtering of portfolio of suggestions by SS sub-council, which are aligned with the manufacturing company’s strategic planning; iii) risk and attractiveness analyses by SS sub-council; iv) designation of projects by sponsor; v) initiation of project by champion; vi) creation of action plan by black belt; vii) closing of projects by executive.

Risk: all projects were evaluated in terms of risk and attractiveness. In selecting projects, LSS take into account: alignment with the strategic plan; return on investment (ROI); innovation; establishment of a performance base; prioritization of value-added projects; resources, time, and liability. The former is based on availability of reliable project data and costs, among other factors. The latter includes potential increase in sales and ROI.

TABLE 6.
Project risk analysis.

Risk (R)	I	E	Very high = 4	High = 3	Low = 2	Very low = 1
Viability (time-months)	3	T	> 20	20-12	12-6	< 6
Dimension (expenses US\$K)	5	T	> 300	300-200	200-50	< 30
Complexity (project data)	3	T	unavailable	difficult to assess	easy to generate	available
Stakeholders involved	4	S	all	key	one	none
Attractiveness (A)	I	E	Very high = 4	High = 3	Low = 2	Very low = 1
Sales (annual increase US\$MM)	4	S	> 5	5-2	2-1	< 1
Cost reduction (US\$K/year)	5	T	> 500	500-300	300-200	< 200
Reducing defects (PPM)	3	T	> 300	300-150	150-100	< 100
Alignment with strategic plan	4	S	very strong	strong	moderate	weak

Legend: I = importance; E = Expression (aspects); T = technical, S = strategic.

TABLE 7.
Phase 3 (Implement projects).

Description
Lean manufacturing (LM) uses the value stream mapping (VSM) that is applied to add value as follow: VSM state (current): describes flow of information from client to plant and material from plant to client; discovers wastes; calculates the value added; VSM state (future): reduces costs; applies LM tools; introduces kaizen (means change for the better, is a methodology to lower costs and improve productivity).
Six sigma (SS) methodology uses Dmaic sequence focuses on improvement and emphasizes planning prior to performing any action, and only value-added processes should be implemented: to ensure implementation, an organizational guide with well-defined functions, such as black and green belt should be established. And it uses market research to hear the voice of the consumer in order to meet critical to quality (CTQ) requirements through, quality function deployment (QFD) and failure mode and effects analysis (Fmea); projects to be developed should be finalized in accordance with Dmadv cycle and the project charter, and their actions should set forth the following: problem to be resolved and goals to be achieved; performance boundaries and baseline for related processes; select potential solutions; anticipated financial outcome; project coordinator and work team; activities and deadlines of each project phase.
Stakeholder: the involvement of stakeholder revealed the following in regard to attitudes towards organizational change from previous (opposition) to future (commitment) to reach the success in the project on.
Stage-gate: the tollgate is another significant process, it is operated by the committee that authorizes the transition from one stage to the next: 1 st (assess whether the project is aligned with the enterprise’s strategy; evaluate attractiveness versus risk; assess technical feasibility evaluate stakeholder requirements); 2 nd (evaluate the probability of meeting critical to quality (CTQ); identify the environmental and safety aspects; measure quality levels and set goals, evaluate ROI); 3 rd (verify that tooling design attains CTQs; evaluate small scale production results; confirm market needs); 4 th (confirm customer approval of field test; recalculate ROI; review lessons learned; close project).

Case study

The manufacturing company at which the case study was conducted is located in southeast Brazil. The Brazilian site produces forged (450 employees, two shifts) for its multinational parent corporation, whose headquarters in the United States and which employs 90,000 staff in 190 sites in several countries. The case study provides evidence that the LSS methodology stimulates the incorporation of key elements from lean manufacturing and six sigma. The advent of new methodologies has substantially altered processes in the

manufacturing company and has contributed to the success of companies whose CEOs recognize that further improvements are needed in today’s competitive markets.

Table 9 shows the application of the tools applied in the case study. In this table the tools are separated by their origin methodology, either LM or SS.

Hot forging cell automation (VSM/Dmadv) select personnel, risk and attractiveness analyses, project charter on the project in a forging business unit is about hot forging cell automation. It uses functional structure described in the framework and it defines: forging impact; goal, innovation, establish project charter (goal: reduce labor 35% by 04/15/2016; team: black belt (leader), engineer, operator; stakeholders: shareholders, customers, suppliers, employees, society; limitation of scope: robot application, and scheduling (Gantt: Define: 01-03/2015; Measure: 02-06/2015; Analyze: 04-07/2015; Design: 05-11/2015; Verify: 10/2015-04/2016). Table 10 shows Dmadv cycle.

TABLE 8.
Phase 4 (Monitor projects).

Monitor: in the outcome monitoring, stakeholders value this framework, but the manufacturing company must apply them with the full commitment and involvement of its staff and human resources. One way to promote participation is to identify critical success factors and redefine performance measurement accordingly with established goals or KPI for each factor and business process.

Lessons: in this assessment, lessons learned, should be aligned with the enterprise’s KPIs and with the finance department. One way to assess this alignment is to determine: the financial impact result; focus on metrics; development on the profit margin; by focusing on proactive actions; the result of its implementation will meet stakeholder expectations; disseminated by other business units.

TABLE 9.
LM and SS tools in the case study.

Tools	VSM	Dmadv	VoC	QFD	SW	CFM	Fmea	takt time	poka-yoke
LM	x				x	x		x	x
SS		x	x	x			x		

TABLE 10.
DMADV cycle.

D: Define project charter, using voice of customer (VoC). The hot forging ensures adequate material flow to attain the desired shape and involves the manufacturing processes: (i) cutting billet; (ii) cell forging; (iii) normalizing; (iv) deburring; (v) blasting. Initially was did the current VSM-state for cell forging.

M: Measure critical to customer needs by quality function deployment (QFD). The introduction of each automation was planned based on takt time, the cycle time allowing production attuned to demand to be carried out in the time available, calculations and involved successive balancing, using standardized sork (SW) and continuous flow manufacturing (CFM) studies of operating times to ensure operational efficiency.

A: Analyze best solution using failure mode and effect analysis (Fmea). Establish the cell automation that are necessary to balance the cycle time. The takt time as follow: calculate your demand, what does your end user or customer typically want every day/week/month and your available time. Takt time = available time / customer demand (daily).

D: Design new concepts (Figure 2). Automation follows a design focused which the operator feeds the induction furnace, using a feeder bowl, which carries the billet by means of vibration to the furnace entrance. Automation of this process enhances safety as it was previously carried out manually in a risk-prone area. In transferring the billet from the induction furnace to the first stage of forging, the operator was exposed to high levels of sound and heat. Lubrication of the die, which had been carried out by an operator positioned in front of the press, was also automated with the installation of a sprayer. Poka-yoke was applied to this process, installing a pick-and-place robot connected to a pyrometer to measure the core temperature of the billets and prevent hot forging at non-specified temperatures. Another change involved the functions of the turnover operator freeing him to inspect forged products. It was did the future VSM-state.

V: Verify meets to customer needs. To maximize the use of available labor, the forging plant transferred some staff to the manufacturing of other cell equipment to meet new production needs arising from increased market demand. Thus, the gradual implementation of all project measures during the period considered, increases 40% monthly productivity per employee in tons forged (from 5 operator to 3 operator). Monitoring KPI and lessons learned after project concluded, it is necessary monitoring results and improving lessons learned: there are a total of [gain: 2 operator per shift x 3 shifts x 4 cells] resulting 24 operator that can be moved to different cells. The lay-out will be rearranged: in the first operation, the saw will be beside the induction furnace. In the mechanical press will use installed automation; it will be developed a perlitic-forge system.

RESULTS AND DISCUSSION

The new framework proposed in this paper emerged from a synthesis of successful practices described in the studies reviewed. This body of knowledge has revealed significant common points, such as added value mapping, which continue to help us identify opportunities for implementation in improvement.

As Table 11 shows, in the papers studied, people selection predominates (personnel) (Vinodh et al., 2011) while project selection (portfolio) is seldom used (Hu et al., 2008). On the other hand, the Dmaic cycle is prominent (Chaurasia et al., 2016). The consensus of the reviewed studies is that after implementing LSS projects, KPI should be applied (Drohomeretski, Costa, Lima, & Garbuio, 2014). The duration of this follow up, however, is not stipulated, although good practice recommends financial monitoring for a year. In the studies surveyed, only one paper briefly described this system. The application of VSM simultaneously with Dmaic was seen in diverse articles, but the application of Dmaic in conjunction with Dmadv was not often seen (Montgomery, 2010). There was a single study that simultaneously presented VSM, Dmaic, and Dmadv, but it did not demonstrate a practical case (Drohomeretski et al., 2014). Our study tries to bridge this gap. In the elaboration of the proposed framework, articles with focus on the manufacturing area were firstly considered. Also it was considered articles of general applications, as example Snee (2010) and service application (Chaurasia et al., 2016).

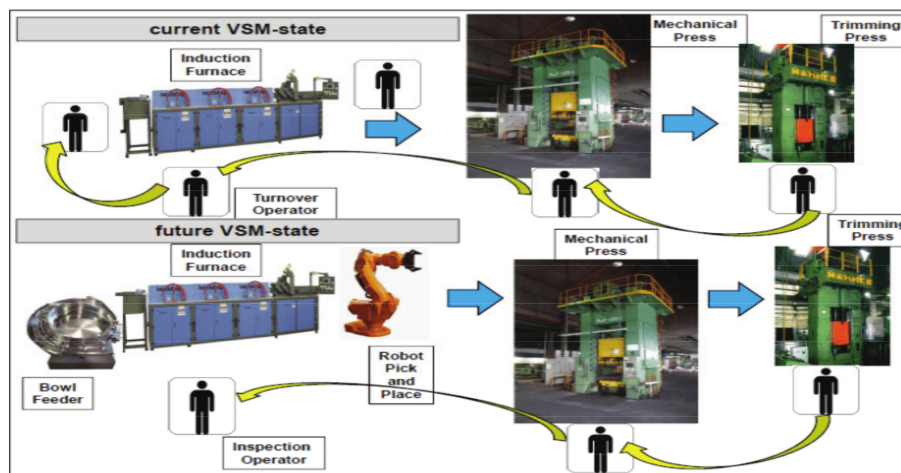


FIGURE 2.
Cell forging: current and future VSM-state.

TABLE 11.
The proposed LSS framework versus literature.

LSS characteristics found in the paper	Paper																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Motivation			x	x	x	x	x				x	x		x			x		x
Leadership					x	x		x					x	x				x	
Personnel					x	x							x		x				x
Portfolio	x							x											x
Risk	x		x																x
VSM				x			x			x					x	x		x	x
Dmaic		x				x	x	x	x	x	x	x	x	x	x	x		x	x
Dmadv						x		x							x				x
KPI															x		x	x	x
Lessons		x					x												x
Area	G	M	G	M	M	G	G	G	M	M	M	G	G	G	M	S	M	M	M

1: Hu et al. (2008); 2: Näslund (2008); 3: Barnes and Walker (2010); 4: Chen et al. (2010); 5: Jeyaraman and Teo (2010); 6: Montgomery (2010); 7: Snee (2010); 8: Sokovic et al. (2010); 9: Vinodh et al. (2011); 10: Gibbons, Kennedy, Burgessand, and Godfrey (2012); 11: Gnanaraj et al. (2012); 12: Hilton and Sohal (2012); 13: Okhovat

et al. (2012); 14: Assarlind et al. (2013); 15: Drohomerski et al. (2014); 16: Chaurasia et al. (2016); 17: Shokri et al. (2016); 18: Swarnakar and Vinodh (2016); and 19: Proposed. G: general; M: manufacturing; S: service.

It was demonstrated that proposed LSS leads a company to competitiveness. It presents an organizational structure dedicated to the methodology (Shokri et al., 2016), which selects projects whose portfolios align with strategic planning (Hu et al., 2008). This selection is undergirded by risk assessment and stakeholder involvement. Although the reviewed studies applied LSS, their practical validity should be assessed in terms of lessons learned (Näslund, 2008). The results should be disseminated to the other business unit (Shokri et al., 2016).

Analysis of the relevant papers found in the study's literature review confirms that any paper in the literature proposed an LSS framework like the one that proposed combining VSM at the same time with Dmaic or Dmadv. In addition, the framework proposed in this research also elaborates risk analysis through the personnel, adopts action plan: stage-gate control, stakeholder involvement, and it emphasizes that, on completing implementation, the ROI should be monitored for a year and the present study highlights the monitoring by KPI and lessons learned. These characteristics are not found together in any LSS framework previously published in the literature.

This article analyzes the organization, implementation, and lesson learned of projects based on the Lean Six Sigma approaches, and identifies the motivations that underpin these approaches and which may prevent users from obtaining the greatest possible benefit from their implementation of LSS. Nevertheless, organizational obstacles may hinder implementation of LSS. And even when well planned, there remain clear standards that serve as a reference for driving and sustaining performance improvement.

CONCLUSION

The present study proposed and implemented a Lean Six Sigma framework. The main findings of the case study highlight the gains in productivity and quality, the reduction of direct workforce in unhealthy area, the automation of the load-unloading providing a better quality of life and safety to the employees of the work cell.

The limitation of the research was to have carried out the case study in manufacturing, which limits the general applicability of the proposal. However, this study can serve as a reference model not only for the industry but also for others interested in adopting LSS approaches in their business, according to their specific needs. Further research should be undertaken to examine the applicability of LSS in a broad spectrum in different segments of companies.

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