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Impacts of Lean Six Sigma over organizational sustainability: A survey study

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ABSTRACT

The purpose of this paper was to verify how Lean Six Sigma (LSS) could influence the organizational sustainability through their projects, given that there are few scientific studies that seek to evaluate the relationship that current exist between this tree streams: Lean, Six Sigma and Sustainability. The metodologie used on this study has qualitative point of view, based on experts' perception and collected by survey. The authors structured a questionnaire with 13 impacts of LSS, which was subsequently applied over 106 international LSS experts, with Green Belt, Black Belt, Master Black Belt or Champions certification. The survey investigate the expert perception of LSS influence over the three pillars of the Triple Bottom Line (TBL). There were identified in this study the correlation between LSS and organizational sustainability, principally due to impacts that significantly influence over Financial pillar of TBL. The authors also identified the 5 more influential impacts over organizational were identified and the importance of cost dimension for sustainability in organizations. This study assists in expansion of knowledge about the use of LSS by evaluating the influence of the metodologie over organizational sustainability and providing a deeper understanding of the relationship existing between them. Because of its feature, this study also raises the awareness among governments and companies regarding the weaknesses identified between TBL pillars. The survey application model through the LinkedIn platform presented in this study also shows itself as a possible source of inspiration for future studies. Even with the large volume of articles published about the Green Lean Six Sigma (GLSS) theme, it was not possible to identify papers that aim to verify the impacts of LSS methodology over the organization with a holistic and sustainable point of view. Within this scenario, the present study seeks to fill the verified gap.

1. Introduction

Lean thinking emerged initially with the development of the Toyota Production System, which Taiichi Ohno and associates structured to help Toyota company survival in a scenario of capital and resources constraints during the post-war recovery (Kurdve et al., 2014). A team of engineers of Motorola, led by Bill Smith in the mid-80s, developed the Six Sigma methodology with the goal to improve the performance of the production process, but the methodology was widely disseminated by GE CEO Jack Welch (Shah et al., 2008).

Many authors have sought to integrate these two methodologies in the last few years in order to compose a single implementation model denominated by Sheridan (2000) as Lean Six Sigma (LSS). Pepper and Spedding (2010) define the LSS as a structured and systematic approach for results improvement that perform statistical analyzes in order to reduce the incidence of defects in the final product at 3.4 defects per million and eliminate waste around all the production process. Originally developed in order to increase productivity on the shop floor, the LSS methodology stands as an effective track for improving organizational performance, mainly due to its feature to seek the improvement of processes with the purpose of achieving superior results in cost, productivity and quality (Salah et al., 2010).

The LSS methodology continues to evolve in terms of the application of LSS methodology in other areas of an organization (Antony et al., 2012; Fischman, 2010; Hsieh et al., 2012), beyond the production environment itself, the expansion of the tools used (Kornfeld and Kara, 2013; Lertwattanapongchai and William Swierczek, 2014; Meza and Jeong, 2013) and the development of multiple deployment models (Arnheiter and Maleyeff, 2005; Campos, 2013; Salah et al., 2010).

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The integration between Lean, Six Sigma and Sustainability comes to stand out in the latter year as an innovative field of study, mainly due to the alignment of the logic and systematic approach of the LSS methodology and the need for a more practical model for managing and controlling sustainability in organizations. According to Cherrafi et al. (2016a) the LSS metodologie has a high potential to be the sustentability challenge answer for those organizations that use it as a managament system.

Although the integration between these three methodologies presents itself as a study trend, the existing bibliographic base is still incipient with few studies focused on this field. Through a systematized review of the literature, Cherrafi et al. (2016a) identified only 118 scientific studies in this field of research, of which only 5.6% sought to integrate the three pillars simultaneously: Lean, Six Sigma and Sustainability.

The few studies identified in this area of knowledge focus on creating a conceptual basis for the field (Cherrafi et al., 2016a), on the identification of a conceptual model for the integration (Cherrafi et al., 2016b; Fatemi and Franchetti, 2016; Ho, 2010) or on the definition of similarities and differences between methodologies (Cherrafi et al., 2016a; Garza-Reyes, 2015a). None of the identified studies sought to diagnose the integration between the methodologies as it is to verify the impacts generated by the LSS on the development of a more sustainable management before the integration.

As predicted by the LSS methodology, it is necessary to look first at the current situation experienced (AS IS) before initiating any type of improvement and innovation (TO BE). So the authors identified a gap on the literature regarding the impacts currently generated by the LSS methodology on the three piles of the organizational sustainability: ecological prevention, financial efficiency and social equity.

The set of studies initiated by Freitas and Costa (2017) seeks develop a model to select and evaluate LSS projects in order to achieve a more sustainable management for the organizations, bringing a vision of cause and consequence between the two themes. In this second stage of the study, the authors seek to identify through the perception os experts: How LSS are capable to influence the three pillars of sustainability management through their projects?

In this context, this research seek to map the influence of LSS impacts over organizational sustainability, according to LSS experts perception, verify the impacts that experts indicates as having more influence over organizational sustainability, identify the most impact pillar and identify the dimensions of the LSS that have the greatest influence over organizational sustainability.

The authors conducted this work as follows: Section 2, present a critical review os the existing literature related to the integration of Lean, Six Sigma and Sustainability. On section 3, we exposed the research methodology, with a more detailed presentation of the impacts selected, instrument for data collection and details of the collection of data. On section 4, a presentation about the results achieved and its discussion was developed. section 5 includes the conclusions reached by this work. On section 4, the authors presented these research limitations, implications and suggestions for future works.

2. Lean Six Sigma and organizational sustainability

Organizational sustainability has become, in recent decades, a highly relevant issue for organizations, mainly due to the pressures generated by stakeholders and the change of thinking experienced by society. Because of this scenario, sustainability is no longer an interesting thing to achieve in order to become a market imperative and a relevant competitive advantage (Garza-Reyes, 2015a; Wong and Wong, 2014).

One of the main barriers to better performance in the social and environmental pillars on organizations comes from the idea that economic performance could be affected by the implementation of these improvements (Florida, 1996; Found, 2009). It is possible to perceive in the literature that the impacts on costs and on clients and employees satisfaction mitigate this risk (Cherrafi et al., 2016a).

Creating reports for disseminate the company's results based on TBL had its structured concept initially in 1997 by John Elkington and was designed with the main objective to incorporate metrics related to impacts generated on society, environment and organization's economic performance, creating a continuous process of management, measurement and accountability of results achieved (Chapman and Milne, 2003; Tyrrell et al., 2013; Wood and Garnett, 2010).

In their study, Singh et al. (2009) identify the existence of 41 different indices, organized in 12 categories, to measure sustainability. Despite the high number of indexes available, the authors highlight the need for a more rational and easy-to-apply model for assessing sustainability in the activities currently performed by organizations. According to Bebbington et al. (2007) “There is a widely recognized need for individuals, organizations and societies to find models, metrics and tools for articulating the extend to which, and the ways in which, current activities are sustainable”.

In this context, multiple authors present the LSS as a management system capable of achieving measurable results for the sustainability of organizations through a structured and continuous method of continuous improvement. Cherrafi et al. (2016a) points out in his work that the integration between Lean, Six Sigma and Sustainability presents potential to generate a system for continuous improvement more effective and well organized, especially in organizations that already apply these strategies.

Initially, the integration between Lean and Sustainability was the most studied, since the focus on waste elimination is common between the two strategies and elevates the potential of its integration (Cherrafi et al., 2016b; Garza-Reyes, 2015a). In this union, the Lean provides tools and courses of action that enable the elimination of waste and sustainability provides a visualization of the impacts generated by environmental, social and financial perspectives (Garza-Reyes, 2015b). Subsequently, researchers have highlighted the need to include of Six Sigma in this formula, bearing in mind the latent need for a rational, disciplined, quantitative and structured model to solve problems and achieve real results (Banawi and Bilec, 2014; Cherrafi et al., 2016a; Furukawa, et al., 2016; Sagnak and Kazancoglu, 2016).

The guide developed by the U.S. Environmental Protection Agency (EPA) present several business cases (3M, General Electric, General Motors, etc.) of interaction between the Lean and the environment to prove the benefits generated through their integration. According to the guide, the improvement actions generated by this integration help to incorporate a philosophy of continuous improvement help eliminate waste and increase team engagement.

Cherrafi et al. (2016a) notes that the integration between Lean, Six Sigma and Sustainability has the strategic goal of improving the organization performance, regarding its performance in the environmental, social and economic pillars, with the help of LSS tools and standards. The authors still flag the need for new techniques and tools that will support this integration.

According to Kumar et al. (2016), six sigma, lean, agil, resilient, green and world-class standard strategies are widely used by business organizations to achieve sustainability criteria, demonstrating a trend in the market, especially for manufacturing companies.

Cherrafi et al. (2016b) identifies in their work evidences that the

integration of these three research streams has high complexity, as well as the one already presented by the integration between Lean and Six Sigma and that the knowledge about the synergy and conflicts between this three streams is yet in its infancy. It is also possible to observe that the environmental pillar of the TBL was the most developed in literature, in detriment of the social pillar.

Other authors present an inverse point of view regarding sustainability with LSS, arguing that the training model currently practiced in the implementation of LSS has a high focus on the exposure of tools and little focus on the human factor present in the projects and the sustainability of the results generated (Dahlgaard & Mi Dahlgaard-Park, 2006). Although the existence of evidence in the literature of the need to integrate the LSS with concepts of organizational sustainability, few studies seek to explore this field of study, leaving a gap on literature that authors explored in this article.

2.1. Identification of existing bibliography

In order to evaluate de Lean, Six Sigma and Sustainability field of research, the authors conducted a survey of articles and reviews published in journals on Scopus base. The authors selected the Scopus base for the application of the survey, since it consists of the world's largest database of peer-reviewed literature and it has more than thirty-five thousand sources, including the publishers: (i) Elsevier, (ii) Emerald, (iii) Springer and (iv) Taylor & Francis.

The survey occur on January 2017 using the following query string: (TITLE-ABS-KEY (Lean) AND TITLE-ABS-KEY (“Six sigma”) AND TITLE-ABS-KEY (green OR sustain OR sustainability OR sustainable)) AND (LIMIT-TO (DOCTYPE, “ar”) OR LIMIT-TO (DOCTYPE, “re”) OR LIMIT-TO (DOCTYPE, “ip”)). The search found 100 Articles, Articles in press and Reviews that formed this section basis.

We evaluated the collected documents by reading their titles, abstracts and keywords in order to identify the outline of the existing bibliographic base and identify articles with greater adherence to the present study. Among the 100 documents, it was possible to identify that four of them were not directly related to the three research streams (Lean, Six Sigma and Sustainability), and then were classified as “Not related”. The following section discuss the identified base of documents by evaluating the (i) study industry, (ii) study focus, (iii) methodology and (iv) research stream.

An analysis of the reviewed studies (Fig. 1) identified that the vast majority of them present (i) Health as the studied industry, with 27 papers in this area. This result is justified due to the increasing need for improvement in the care and management of resources through hospitals and health units, which is evident with a view to the high volume of scientific studies aimed to apply management techniques in this area (De Koeijer, Paauwe & Huijsman, 2014; Ha et al., 2016; Kelly, 2016). Furukawa et al. (2016) also emphasizes that the application of the LSS in health helps reducing costs, reducing errors, improving patient safety and quality of health care.

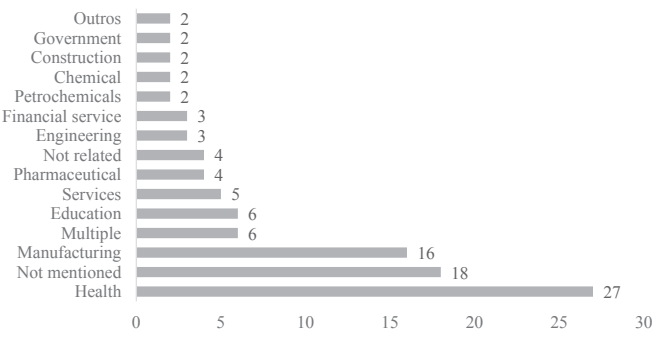

Fig. 1. Industry studied by the authors.

In 18 studies there was no focus industry and most of them were generalist bibliographical studies (Arcidiacono et al., 2016; Jourabchi et al., 2014; Kumar et al., 2016). The manufacturing industries appear only in third place in this analysis, with 16 documents, being possible to identify studies in the aviation industry (Chakravorty and Hales, 2017), automotive industry (Huehn-Brown and Murray, 2010), paper industry (Burton, 2005), among others.

Through the analysis of the selected studies purpose (Fig. 2), the authors identified that most of the studies focused on (i) evaluating the application of the method in organizations, which can be Lean, Six Sigma or Lean Six Sigma. In most of these studies, the authors evaluated the application through the analysis of a single case (Arif, 2016; Savage and Sreevathsan, 2016), however it was possible to identify works that comparatively evaluate multiple application cases (Found and Harrison, 2012), evaluate the results reported in other articles (Svensson et al., 2015) or evaluate its application at city level (Brandt, 2011).

It was still possible to identify a large number of studies that aimed to (ii) develop a conceptual model for implementation (Chakraborty and Leyer, 2013; Lee and Wei, 2010) or integration (Kumar et al., 2016). Other studies only (iii) show the results achieved with the application of the method, without conducting a deeper critical analysis of the methods used through the results achieved (Donovan et al., 2016; Xu et al., 2016) or perform an (iv) evaluation of the existing bibliography (Aleem, 2013; Sunder and Sunder, 2016).

Fig. 3 shows the study methods used by the authors, being the (i) case study the most frequent and present in 53 documents as one of the methods used. Is important to highlight that 18 of these studies used the health area as the industry to the application. The literature review also stands out as a method widely used in the studies, with 39 studies.

Through the carried out analyzes, it was possible to identify that there is a saturation regarding the accomplishment of case studies and bibliographical researches in this research field, mainly with the focus on the evaluation or presentation of the applied method and the development of conceitual models. It is then identified the need to explore new research methods and focuses within this area, and the existence of space for new studies.

In order to probe the relationship between LSS and Sustainability, the authors evaluated the articles surveyed in order to verify the streams studied by each article (Fig. 4). The authors identified that only 10 articles, out of the 100 evaluated, deal with the three streams together, value considered low for such a promising field of research. Is important to highlight the existence of other articles that claimed to study the sustainability of the LSS, but in this cases de sustentability was related to the perpetuation of the results achieved by projects and were not focus on the attending of financial, social and environmental issues (Chakravorty and Hales, 2016; Thomas et al., 2008; Samarrokhi et al., 2015).

The authors developed an analysis to verify the metodologia and the study focus used by the authors of the 11 articles selected. Through the analysis matrix (Table 1) it was identified that most of these papers use the bibliographic revision method in order to develop conceptual models for integration of Lean, Six Sigma and Sustainability (7). In only three cases, the authors applied the proposed conceptual model through a case studie. Only one article selected had the survey as one of the methods used on the article and the authors applied this method to identify model's critical factors of success.

This analysis evidences the need to explore other focus within this field of research. Some examples are: (i) the evaluation of the

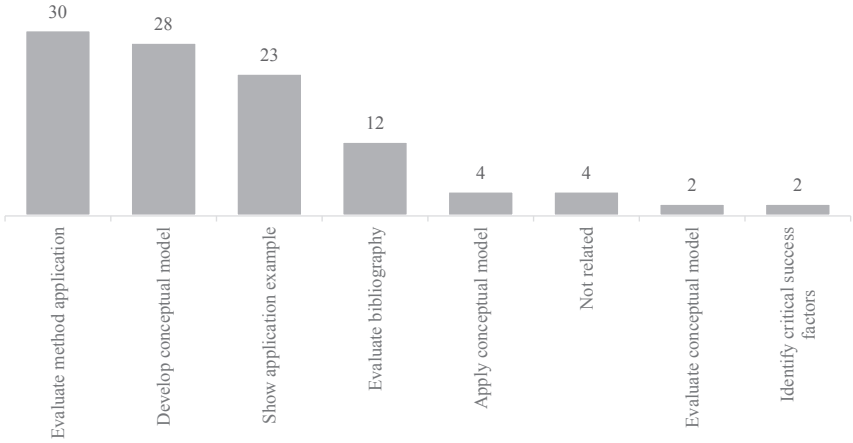

Fig. 2. Focus of the developed study.

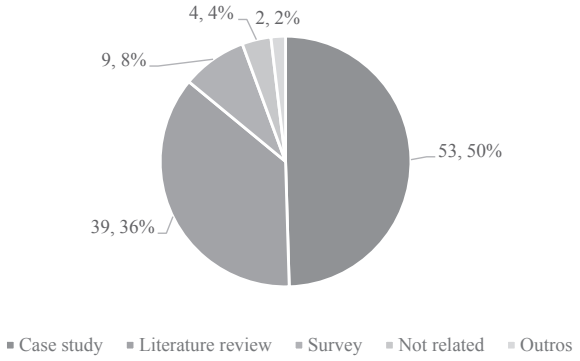

Fig. 3. Methodology used by authors.

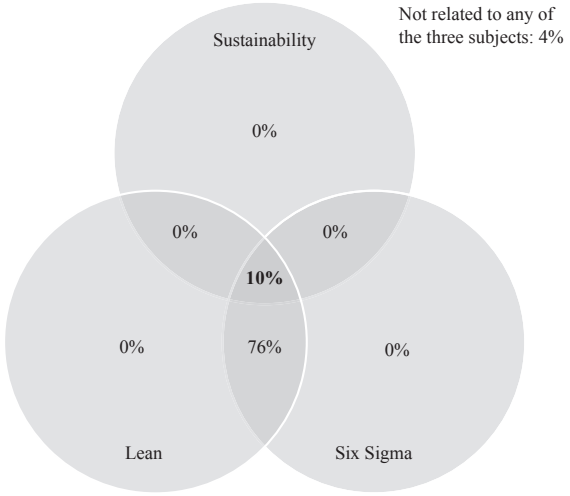

Fig. 4. Distribution of the study stream.

impacts generated by the LSS on sustainability, (ii) adaptation of LSS tools to a more sustainable vision, (iii) selection of LSS projects based on sustainability criteria and (iv) evaluation of the results achieved by projects in the social and environmental pillars, going beyond the financial point of view. This studie seek to fill the first presented gap, because it assesses the impacts generated by LSS projects on the three pillars of organizational sustainability through the perception of experts with a high knowledge of the methodology. The next session presented and evaluated the eleven selected studies.

2.2. Evaluation of existing bibliography

Cherrafi et al. (2016a) presents in their first study a critical review of the existing literature with the intention of structure a body of knowledge regarding the integration between Lean, Six Sigma and Sustainability, formulating guidelines to construction of a conceptual model. In this study, the authors presented drivers, barriers, benefits and critical success factors of a possible integration model. It is also possible to found on the article a bibliometric analysis of temporal, geographical and sectoral distribution of the existing literature.

The authors also point out 19 different benefits generated through a possible integration, among them: (i) increase in team morale, (ii) cost reduction, (iii) profitability increase, (iv) efficient use of resources, (v) risk reduction and (vi) improvement of the company's reputation. Despite the depth of the content, the article does not yet provide a model for integration or measurement for the methodologies.

In a later study, Cherrafi et al. (2016b) presents a five-stage and sixteen-step model for the integration of these strategie, that was developed based on an analytical review of the existing literature. For the model development, the authors used fourteen peer-reviewed journal articles and presented the three most relevant models with more detail. They also identified five central gaps in the evaluated literature, which served as a basis for the proposing the model. The authors suggest the following stages of integration of strategies: (i) conceptualization, (ii) implementation design, (iii) implementation and evaluation, and (iv) knowledge sharing and culture development. Four companies, from different industries (food, textile, tannery and hotel), implanted the proposed model, having achieved significant results in reducing energy consumption and reducing water consumption. It is possible to identify, through the results achieved, a focus on the TBL environmental pillar. In addition, the integration model developed focus on increasing productivity, reducing resource consumption and reducing impacts, showing a tendency to improve performance for the TBL environmental pillar.

In their study, Kumar et al. (2016) highlight the barriers to the integration of Lean, Six Sigma and Sustainability for the product development process. The authors used a literature review and brainstorming evaluation as research methodology, and it was possible to identify twenty-one barriers as a result. The authors also

Table 1
Methodology used by Green Lean Six Sigma articles.

		Methodology		
		Literature review	Case study	Survey
		Qnt	Qnt	Qnt
Focus	Develop conceptual model	7	–	–
	Apply conceptual model	–	3	–
	Identification of critical success factors	1	–	1
	Evaluate bibliography	3	–	–
	Show application example	–	1	–

identified, using interpretative structural modeling, the importance hierarchy of the evaluated barriers. The study focused on India's automotive sector, identifying seven driving barriers, nine dependency barriers, five link barriers and no autonomous barriers. The study classified the lack of commitment of the high management as the main input to eliminate other barriers and the competition and uncertainty as the outputs most generated when the barriers was not mitigated.

Fatemi and Franchetti (2016), sought to study the possible use os Six Sigma for the application of Lean and Green strategie. The authors present the results achieved by Six Sigma over the economic, social and environmental pillars in a cell manufacturing process. The results indicate the existence of improvements in cost and environmental criteria through application Six Sigma application. Although integrating Six Sigma with sustainability and Lean strategies in the specific case study, the authors made little use of Lean tools and other benefits of this philosophy, which go beyond the elimination of waste.

Furukawa et al. (2016) in their study, presents a different point of view. The authors analyze the sustainable actions performed by an intensive care unit team through LSS projects in order to improve medication process performance. The authors justify the use of the LSS approach arguing that it focuses on waste reduction, without undermining patient safety. This study presents interesting results, especially for large hospitals that generate a large volume of waste, because it present a wide range of improvement actions, classified as dependent (8), independent (5) and complementary (5). For this analysis, the authors used results of over 324 processes, before and after the implementation of sustainable actions, reducing the use of packaging and plastic bags and the cost of materials disposal. It is possible to notice that this study still presents a very strong focus on environmental pillar; in addition, the steps of application of the LSS are not clear.

Through an evaluation of the existing literature and a the application of a case study, Sagnak and Kazancoglu (2016) identify the limitations of Green Lean and evidence Six Sigma as a possible strategy for its elimination. The study presents as methodology the Measurement System Analysis and the Gage Control and the authors carried out thi study focusing on the operational area. The study drivers were the waste elimination, the focus on process and the high level of participation. Despite encouraging the participation of those involved, the project still has a very high focus on the TBL environmental pillar, with no mention of the social pillar.

Kumar et al. (2015) used a series of methodologies to conceptualize the integration between the three streams: literature review, interviews, workshops, brainstorming, questionnaire application and statistical analysis. The authors present as a result of the research the definition of an integration model, which takes into account 29 implementation barriers, 44 enablers, 12 performance indicators and 9 critical success factors based on an empirical study. The authors developed the proposed model through a literature review and then a master black belt and a black belt in LSS evaluated the results. The authors also raised critical factors for the integration success through the application of a survey. This study is the only one that presents the social pillar as a main goal.

The paper elaborated by Garza-Reyes (2015b) demonstrates the need to integrate Green Lean with Six Sigma through a critical evaluation of limitations, examples, concepts, purposes and method. The authors carried out this evaluation based on a systematic literature review that indicated that Six Sigma may assist in mitigating of some Green Lean limitations. The authors question throughout the study whether it is possible to achieve a competitive operation and positive environmental results at the same time. The model application was not on the study scope, however, it appear as suggestion for future work. The main evolution presented by this study was the creation of a comparative summary framework between Green, Lean and Six Sigma, based on their definitions, purpose, focus, measures, KPIs, realized dimensions, techniques and tools.

Banawi and Bilec (2014) also develop an integration model for Lean, Green and Six Sigma, with the goal of improving environmental performance and quality in the construction industry. With the aim of illustrating and proving the results, the authors applied the proposed model in pipe installation process with focus on waste elimination. This study presents the delay and the estimation error as the main causes of waste in the studied case, besides presenting the changes in project's design, as the cause of 60% of waste, according to professional's opinion. The model used the DMAIC (define, measure, analyze, and improve) steps from Six Sigma for structuring the model, that the author grouped in three major steps: (i) define and measure, (ii) analyze and improve and (iii) Control. The model also considered other strategies and tools, such as: (i) value stream mapping, (ii) life cycle analysis, (iii) cause and effect diagram and (iv) Pareto chart. The duration and the experience were limiting factors for this research.

Ho (2010) presents the oldest study of this field, and sought to develop a Lean TQM model for sustainable development focused on safety, hygiene, quality, productivity, image, costs, environmental protection and delivery. The core of the article was the exposure and evaluation of practical examples that served to elaborate an integrated model for ISO 9000, ISO 14001, OHSAS18001 and Six Sigma. The author presents the 5S+ audit methodology, previously developed by him, and used it as the evaluation structure, because he claims that this tool helps organizations to know “2what” to do, even if they do not say “how” to do it. The policies and requirements of the three integrated streams form the model objectives and goals that later should help to manage resources and processes according to them.

Another important aspect of this study field is the existence of conflicting nomenclatures regarding the notion of integration between Lean, Six Sigma an Sustainability. The authors identified in literature the terms Green Lean Six Sigma (Cherrafi et al., 2016b; Garza-Reyes, 2015b; Kumar et al., 2016) Sustainable Green Lean Six Sigma (Kumar et al., 2015), Sustainable Lean Six Sigma (Kumar et al., 2015) and Lean and Green strategy with a Six Sigma approach (Fatemi and Franchetti, 2016). For the development of this study the Triple Bottom Line Lean Six Sigma (TBLLSS) term was adopted, since it is the term that makes clear the importance of achieving results for economic, social and environmental pillars through the LSS, without focusing on environmental aspect and not only related to the perpetuation of economic results.

The authors could identify, through this bibliographic review, the existence of unexplored gaps regarding the integration of LSS

with the three pillars of sustainability. The need for integrated models to measure the LSS based on the performance of the social, environmental and financial pillars is latent. We also identified the creation of many models based only on conceptual review and few practical ones, which did not fully evidential the relationship between these three streams, with no previous study evaluating the existing interaction before proposing a model.

Due to the presented scenario, becomes apparent the lack of knowledge about the impacts generated by the projects developed based on the methodology proposed by LSS on the three pillars of organizational sustainability before the implementation of an integration model. It is also evident that the previous studies did not explore the opinion of experts, since none of them used survey as the research methodology.

3. Research methodology

In order to reach the defined goals of this research, it was structured from a qualitative point of view, based on survey research model, with data collection conducted through bibliographical research and application questionnaire, and it was structured into 4 steps:

(i) **Selection of impacts:** It consists on the survey in scientific literature of impacts generated by the application of LSS methodology on organizations;
(ii) **Instrument development:** Development of a questionnaire with closed questions to be used in data collection stage;
(iii) **Data collection:** Apply the online instrument developed to collect the perception of LSS experts around the world;
(iv) **Analyses of collected data:** Analysis of data collected through qualitative methods and descriptive statistics in order to answer the research questions proposed by the work.

The following research questions were structured and used to guide the organization of the data collection instrument and the data analysis:

(Q1) Experts perceive the correlation between LSS and TBL?
(Q2) What is the TBL pillar most impacted by LSS according to experts?
(Q3) What are the most influential LSS impacts to the TBL according to experts?
(Q4) There is a correlation on the influence of LSS between the pillars of TBL?
(Q5) There is a correlation between the influence of the impact on the TBL and its relevance in the literature?
(Q6) What is the most influential dimension to the TBL and its three pillars according to experts?

3.1. Selection of impacts

Several studies explore the impacts generated by LSS projects in the organizations that use this metodologie (Atmaca and Girenes, 2013; Corbett, 2011; Drohomeretski et al., 2014; Habidin and Yusof, 2012; Jeyaraman and Kee Teo, 2010; Prasanna and Vinodh, 2013), but none of these studies focus on identifying the most relevant impacts for literature or assess these impacts by organizational sustainability perspective.

It is relevant to notice that this study complement the previous on reported in Freitas and Costa (2017), that is focused on understanding the impacts generated by LSS in organizations. In order to identify the impacts generated by the use of LSS in organizations, Freitas and Costa (2017) developed a systematic study over the available literature. Through research conducted in SCOPUS bases the authors identified a total of 719 records related to the LSS subject, having been refined 396 articles and reviews published in journals and subsequently selected the 48 records that has more alignment with the subject, and which were used as basis for the literature review.

From the analysis of the selected records, 25 impacts caused by the use of Lean Six Sigma in organizations were identified, as well as the frequency with which they were cited by the authors. The authors also identified the 13 impacts that was most cited by the authors through a Pareto analysis, which selected the impacts that represented 80% of total citations in the literature (Fig. 5).

Among the most cited impacts, we identify five tha were directly related to the size of costs, three were related to quality improvement and five to customer satisfaction (Fig. 6). This segmentation

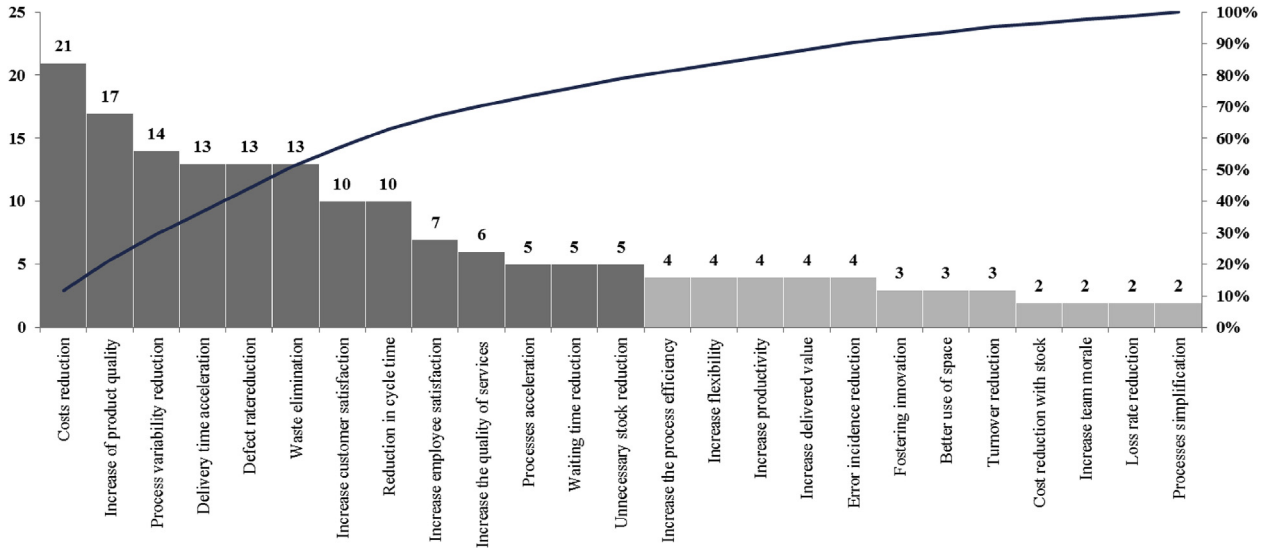

Fig. 5. Pareto analysis of the impacts identified based on the literature review.
(Source: Freitas and Costa, 2017).

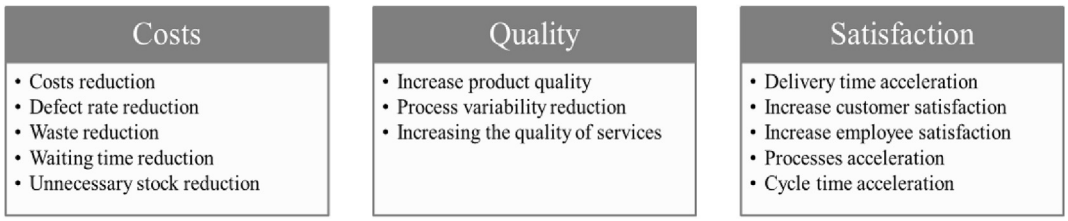

Fig. 6. Thirteen more frequent impacts by dimension.
(Source: Freitas and Costa, 2017).

showing the concern of companies with increasing revenues through improved its products and services, combined with customer satisfaction and a constant search for better placement in costs (Freitas and Costa, 2017).

The 13 LSS impacts selected for this research structuration, as well as their identification codes, volume of citations, authors and description, are exposing by Table 2.

The research carried out by Freitas and Costa (2017), shows its relevance because, according to Garza-Reyes (2015a), the Impact on Organizational Performance is on of the six most relevant research stream about "lean-green", but it was not possible to identify, on scientific literature, researchs that present a collection of the

Table 2
LSS impacts selected for evaluation by experts.

Code	Impact	Citation	Description
IPC-01	Costs reduction	21	Understands the achievement of better results in costs through actions focused on reducing the process lead time, waste and resource consumption. This impact is a result of several other impacts, because of that, is has great relevance to the topic and is more frequently cited by the authors. Drohomeretski et al. (2014) shows in his work that the cost reduction focus is on achieving better performance than the one presented by competitors.
IPC-02	Increase product quality	17	The increase in quality of the final product is related to meet customer's needs and requirements with lowest failure rate. LSS helps the organizations to ensure that the products are consistent with what their customers need mainly due to the use of Voice of the customer (Laureani and Antony, 2010).
IPC-03	Process variability reduction	14	It involves reducing the range of variation between process results and its expected performance, becoming an important factor to ensure greater control. By reducing process variability using statistical tools, LSS allows managers to predict the final product generated by the process with higher precision (Corbett, 2011).
IPC-04	Delivery time acceleration	13	Includes the reduction of the time to deliver the product to customer, from its acquisition to its receipt confirmation in the desired location. For Laureani and Antony (2010) is essential to deliver the right product in the right place and, above all, at the right time in order to satisfy customers.
IPC-05	Defect rate reduction	13	Is the reduction of the percentage of final products that have manufacturing defects per unit produced, as well as the frequency of services that present non-compliance in the implementation. Defect can be defined as any aspect that does not meet the needs and expectations of customers (Pepper and Spedding, 2010).
IPC-06	Waste reduction	13	Is the removal of various forms of waste in the production process, such as defects, unnecessary processing, waiting, etc. To Arnheiter and Maleyeff (2005), the various tools used in the LSS methodology, as kaizen and value stream mapping, have the potential to reduce waste in all areas of the organization and generate great benefits with its use.
IPC-07	Increase customer satisfaction	10	Reach the functional needs of customers, with quality of products/services and adequate delivery time, are important requirements to your satisfaction. Salah et al. (2010) state that LSS is a corporate strategy that allows the achievement of competitive advantage by meeting the needs of customers and employees.
IPC-08	Cycle time acceleration	10	Comprises the reducing of production cycle time from its start to the end of the process, it is considered the time required to produce an item. LSS seeks to develop solutions using the minimum amount of resources and making the product reach the customer at the right time (Atmaca and Girenes, 2013).
IPC-09	Increase employee satisfaction	7	It is the increase of team motivation and morale with a better well-being in the workplace; can be reached by LSS, generating increased employee satisfaction. Based on its principles, the LSS has the potential to achieve greater employee satisfaction either by reducing process variability (Campos, 2013).
IPC-10	Increasing the quality of services	6	It encompasses the alignment between the customer perceptions of the service and its expectations, considering all its stages. Lertwattanapongchai and William Swierczek (2014) argue that the LSS is a structured and disciplined methodology that allows evaluating the products and services of the entire value chain through customer perspective.
IPC-11	Processes acceleration	5	Reduction of time spent in activities and acceleration of the overall time to market, since production until delivery of products/services. The LSS has emphasis on achieving faster process, reduce cost and raise quality, enhancing the competitiveness of an organization (Lertwattanapongchai and William Swierczek, 2014).
IPC-12	Waiting time reduction	5	Reduction of the total time that the product is not being transported or worked along the production process. The waiting time may be caused by design flaws, failures in equipment and need to setup. Corbett (2011) states that the less the product remains in the process, the less chance of a defect, breakage and obsolescence.
IPC-13	Unnecessary stock reduction	5	It consists of the acquisition of the appropriate stock volume aligned to the expected demand, avoiding the build-up of raw material and stock in production throughout the process. The excess inventory is not necessary for the success of a process and is traditionally used as a safety net to avoid system stress, becoming a common type of waste (Pepper and Spedding, 2010).

Source: Freitas and Costa, 2017.

impacts of Lean and Six Sigma on organizacional performance.

3.2. Instrument development

The authors used the 13 impacts selected by Freitas and Costa (2017), through Pareto analysis, in the construction of the data collection instrument because of its relevance to this research. In order to facilitate the evaluation of experts perception about LSS influence over the three pillars of TBL (Economic, Social and Environmental), the fallowing range was structured and incorporated to the questionnaire. The authors provided the follow range based on the scale propose by Likert:

- **Very positive:** Impact has a strong positive correlation with the results of the pillar
- **Positive:** Impact has moderate positive correlation with the results of the pillar
- **Neutral:** Impact not have any correlation with the results of the pillar
- **Negative:** Impact has moderate negative correlation with the results of the pillar
- **Very negative:** Impact has a strong negative correlation with the results of the pillar

Kumar et al. (2015) indicates that, although the LSS is clearly environment friendly, it is necessary to evaluate the other negative and positive impacts generated by the LSS, in addition to environmental impacts.

The first question of the survey instrument was structured as a matrix by including the impacts of LSS in rows and adding more three parallel columns for evaluation of the pillars Economic, Social and Environmental. The matrix structure was selected because facilitate the filling of the answer and the comparability between impacts during the evaluation. The authors organized the impacts in random order defined by search tool for each expert to avoid possible trends in responses due to his ordination. To facilitate the understanding of the first questionnaire stage, the following question was developed: **How would you rate the correlation between the Lean Six Sigma impacts listed below and the three pillars of organizational sustainability?**

They were introduced two questions at the end of the questionnaire related to identification of the profile presented by the universe of respondents. The second question inserted on questionnaire was: **At what level you currently operate in Lean Six Sigma projects?** To this question, there were available seven response options: (i) White Belt (ii) Yellow Belt, (iii) Green Belt, (iv) Black Belt, (v) Master Black Belt, (vi) Champions and (vii) Others. The inserted question sought to identify the certification degree of the participant experts and enable further validation of answers and database cleaning. The third research question sought to identify: **What is your country of birth?** and there were provided 16 countries options for response with the "Other" option for experts from countries not available in the displayed list.

3.3. Data collection

The authors selected the LSS experts to participate to the survey were identified through the most relevant professional groups existing on LinkedIn® tool. On November 17, 2015 a search was made on LinkedIn® platform using the keyword "Lean Six Sigma" on the "Groups" bases, with this search the three groups with more number of members were identified:

1° - Lean Six Sigma: 392.813 experts;
2° - Continuous Improvement, Six Sigma, & Lean Group: 98.127 experts;
3° - Group - Lean Six Sigma Worldwide: 36.029 experts.

The authors performed an identification of experts with LSS certification and long experience in the field to participate on survey using the word "Black Belt" on the search operation available inside members section of each group. We selected 520 LSS certified experts and invited to participate. Of the 520 invited experts, 251 agreed to participate, representing 49% of the initial sample.

The questionnaire to assess the effects of LSS over organizational sustainability stayed available to answer between days 1 December 2015 and 14 December 2015, during this period, the results achieved with the data collection were monitored daily through management dashboards provided by the online platform.

Of the 251 experts who received the survey questionnaire for evaluation, 106 responded to it, representing a return rate in data collection of 42%. All responses were considered as valid because they are all filled by Green Belt, Black Belt, Master Black Belt and Champions (Fig. 7).

About the nationality distribution (Fig. 8), is possible to verify that LSS experts from 26 different countries located around the world answered the survey. The five countries with the largest number of respondents were: (i) United States (USA), (ii) India, (iii) Brazil, (iv) Netherlands and (v) UK.

4. Results and discussion

The survey responses was processed in order to group the evaluations "Very positive", "Positive", "Negative" and "Very negative" together to identify all that reviews "With correlation" (WC) received by each impact on the pillars. The reviews "Neutral" were also grouped and classified as "With the correlation" (NC) so it could be compared to the status "With correlation" (WC) posteriorly. The total "Valid responses" (VR) was calculated by adding the reviews "With correlation" with the reviews "With the correlation", thus disregarding the reviews "Do not know/No opinion" (Table 3).

(Q1): Experts perceive the correlation between LSS and TBL?

Table 4 shows the result of the hypothesis testing for a proportion exploring if the number of impacts that received the review "With correlation" in relation to the total number of valid responses to each pillar and the TBL is over 50%, indicating that most specialists identify a correlation between LSS and TBL. To perform the test we defined the following null and alternative hypotheses:

- $\mathbf{H_0}$: $p = p_0$
- $\mathbf{H_a}$: $p > p_0$

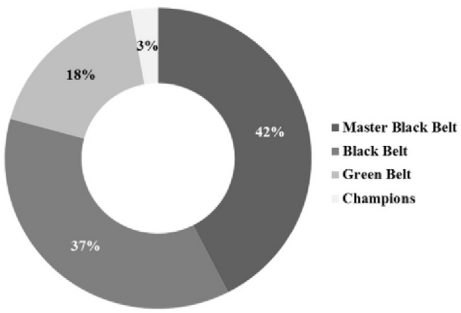

Fig. 7. Distribution of respondents experts by hierarchical level.

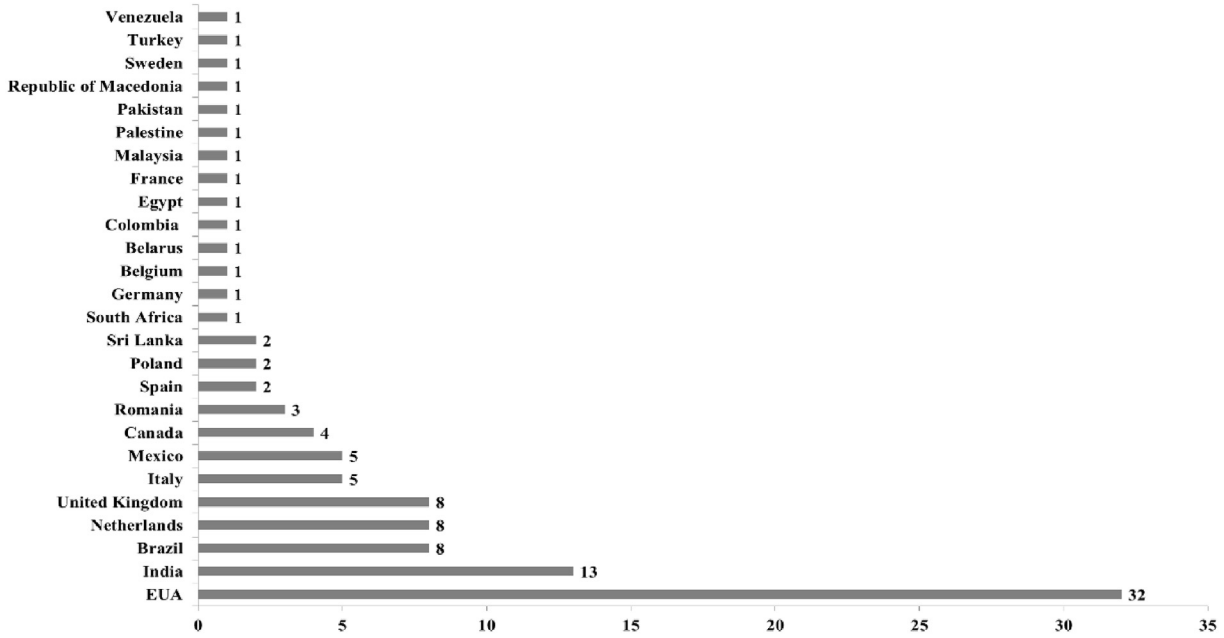

Fig. 8. Distribution of respondents experts by nationality.

Table 3
Frequency distribution of responses collected from the experts.

Impact	Dimension	Environmental			Economic			Social			TBL		
		WC	NC	VR	WC	NC	VR	WC	NC	VR	WC	NC	VR
IPC-01 - Costs reduction	Costs	58	42	**100**	89	2	**91**	69	34	**103**	216	78	**294**
IPC-02 - Increase product quality	Quality	70	30	**100**	101	4	**105**	80	21	**101**	251	55	**306**
IPC-03 - Process variability reduction	Quality	70	29	**99**	101	4	**105**	67	35	**102**	238	68	**306**
IPC-04 - Delivery time acceleration	Satisfaction	50	47	**97**	97	8	**105**	71	30	**101**	218	85	**303**
IPC-05 - Defect rate reduction	Costs	83	18	**101**	106	0	**106**	82	21	**103**	271	39	**310**
IPC-06 - Waste reduction	Costs	93	10	**103**	106	0	**106**	88	15	**103**	287	25	**312**
IPC-07 - Increase customer satisfaction	Satisfaction	51	50	**101**	99	7	**106**	81	23	**104**	231	80	**311**
IPC-08 - Cycle time acceleration	Satisfaction	50	47	**97**	106	0	**106**	66	34	**100**	222	81	**303**
IPC-09 - Increase employee satisfaction	Satisfaction	43	56	**99**	86	20	**106**	90	12	**102**	219	88	**307**
IPC-10 - Increasing the quality of services	Quality	66	32	**98**	100	6	**106**	92	11	**103**	258	49	**307**
IPC-11 - Processes acceleration	Satisfaction	48	52	**100**	100	6	**106**	64	40	**104**	212	98	**310**
IPC-12 - Waiting time reduction	Costs	41	54	**95**	87	14	**101**	63	35	**98**	191	103	**294**
IPC-13 - Unnecessary stock reduction	Costs	79	21	**100**	100	6	**106**	53	48	**101**	232	75	**307**

To a 95% confidence interval, the evaluated proportion (p) would only be higher than 50% if the calculated Z were greater than 1.654 and p-value under 5%. Thus, for all four cases evaluated the null hypothesis could be rejected which shows that, according to experts, the LSS is perceived as correlated with all three pillars of the TBL (Environmental, Economic and Social) as well as the TBL itself. The TBL stands out in this analysis with the highest Z presented (33.8525), followed by the Economic pillar (32.8529), which had a far superior result when compared to other pillars (Social - 16.6756 and Environmental - 8.7425) demonstrating its relevance.

(Q2): What is the TBL pillar most impacted by LSS according to experts?

Next, to identify the pillar more influenced by LSS, we execute a series of hypothesis test between the differences of proportions among the three pillars of TBL in sets of two by two. For this analysis, the following null hypothesis and alternatives were structured:

- $\mathbf{H_0}$: $\overline{p}_1 - \overline{p}_2 = 0$
- $\mathbf{H_a}$: $\overline{p}_1 - \overline{p}_2 > 0$

Table 4
Hypothesis testing for difference between two proportions with a confidence interval of 95%.

	With correlation	Valid responses	p	p0	Standard deviation	Z	p-valor
Environmental	802	1290	0.62	0.50	0.0139	8.7425	0.0000
Economic	1293	1370	0.94	0.50	0.0135	32.8529	0.0000
Social	966	1325	0.73	0.50	0.0137	16.6756	0.0000
TBL	3061	3985	0.77	0.50	0.0079	33.8525	0.0000

On the executed comparison of the proportions presented by two pillars, with a confidence interval of 95%, the proportion presented by the first pillar (p1) would only be upper than the proportion of second pillar (p2) if the calculated Z were greater than 1.654 and p-value under 5%. After the test, it has been identified that only in the third test, were the Economic (p1) and Social (p2) were compered, the null hypothesis could be rejected, indicating that the proportion of reviews "With correlation" presented by first pillar is greater than the second pillar. In the comparative analysis between the Environmental pillar with Social pillar (−21.6644) and Economic pillar (−5.8970), the null hypothesis could not be rejected demonstrating that the proportion of reviews "With correlation" for this pillar is lower than both other pillars (Table 5).

This way, LSS has demonstrated greater influence over Economic pillar, followed by the Social pillar and finally the Environmental pillar, which is the less influenced. The authors also observed that the Environmental pillar has a proportion difference with the Economic pillar four times higher than with Social pillar, showing a strong imbalance in the influence of LSS between the pillars.

(Q3): What are the most influential LSS impacts to the TBL according to experts?

To identify the most influential impacts according to experts, they were developed four rankings of impacts for each pillar and the TBL considering the proportion of "With correlation" evaluations in relation to the total valid responses. On Table 6 is possible to observe that, among the five impacts with major influence over the Environmental pillar, three were related to the Costs dimension: (i) Waste reduction, (ii) Defect rate reduction e (iii) Unnecessary stock reduction. The dimension of Quality also had two impacts in the ranking top five, which are: (i) Process variability reduction e (ii) Increase product quality.

As in the Environmental pillar, it's possible to observe a predominance of the Costs dimension between the five impacts with major positive influence over Economic pillar, which are: (i) Defect rate reduction, (ii) Waste reduction, (iii) Cycle time acceleration, (iv) Costs reduction, (v) Increase product quality e (vi) Process variability reduction. The IPC-05, IPC-06 and IPC-08 impacts presented a tied position in the ranking with a frequency of 100.00%, as well as the IPC-02 and IPC-03 impacts with 96.19%. In the Social pillar, the impacts with more influence over it were: (i) Increasing the quality of services, (ii) Increase employee satisfaction, (iii) Waste reduction, (iv) Defect rate reduction e (v) Increase product quality.

According to the evaluation of the LSS experts, the five impacts that have greater influence on the TBL, considering the ratio of the reviews "With correlation" and the total of valid responses (Table 6), were:

- **1ª)** IPC-06 - Waste reduction: The waste reduction was assessed by experts as the impact with major influence over TBL, having excelled in the Economic pillar (100.00%), Environmental pillar (90.29%) and Social pillar (85.44%), showing the importance of this impact for TBL.
- **2ª)** IPC-05 - Defect rate reduction: The defect rate reduction reached the second position on the ranking of influence over TBL, but did not show the same balance between the pillars identified in the previous impact, reaching the 2nd position of Environmental pillar, 1st position of the Economic pillar, tied with the waste reduction, and 4th position of the Social pillar.
- **3ª)** IPC-10 - Increasing the quality of services: Despite the low number of citations of this impact in the evaluated scientific literature, this proved to be relevant to organizational sustainability, having reached the 3rd position in the ranking of influence over TBL.
- **4ª)** IPC-02 - Increase product quality: This impact appears as one of the six most cited in the scientific literature and also in the list of most influential impact over TBL, having reached the 5th position on the three pillars.
- **5ª)** IPC-03 - Process variability reduction: Despite the emphasis achieved by this impact on Environmental and Economic pillars, which reached respectively the 4th and 5th position among other impacts, it reached only 10th position in the social pillar, with 65.69% of reviews "With correlation" and 34.31% of reviews "With no correlation".

Table 5
Hypothesis testing for difference between two proportions with a confidence interval of 95%.

	p1	n1	p2	n2	Standard deviation	Z	p-value
Environmental Pillar x Economic Pillar	62.17%	1290	94.38%	1370	0.0149	−21.6644	1.0000
Environmental Pillar x Social Pillar	62.17%	1290	72.91%	1325	0.0182	−5.8970	1.0000
Economic Pillar x Social Pillar	94.38%	1370	72.91%	1325	0.0137	15.6698	0.0000

Table 6
Ranking of impact regard the perception of correlation with the three pillars of TBL.

Impact	Environmental		Economic		Social		TBL	
	%WC	Rank	%WC	Rank	%WC	Rank	%WC	Rank
IPC-01 - Costs reduction	58.00	7°	98.11	4°	66.99	8°	74.76	7°
IPC-02 - Increase product quality	70.00	5°	96.19	5°	79.21	5°	82.03	4°
IPC-03 - Process variability reduction	70.71	4°	96.19	5°	65.69	10°	77.78	5°
IPC-04 - Delivery time acceleration	51.55	8°	92.38	11°	70.30	7°	71.95	10°
IPC-05 - Defect rate reduction	82.18	2°	100.00	1°	79.61	4°	87.42	2°
IPC-06 - Waste reduction	90.29	1°	100.00	1°	85.44	3°	91.99	1°
IPC-07 - Increase customer satisfaction	50.50	10°	93.40	10°	77.88	6°	74.28	8°
IPC-08 - Cycle time acceleration	51.55	8°	100.00	1°	66.00	9°	73.27	9°
IPC-09 - Increase employee satisfaction	43.43	12°	81.13	13°	88.24	2°	71.34	11°
IPC-10 - Increasing the quality of services	67.35	6°	94.34	7°	89.32	1°	84.04	3°
IPC-11 - Processes acceleration	48.00	11°	94.34	7°	61.54	12°	68.39	12°
IPC-12 - Waiting time reduction	43.16	13°	86.14	12°	64.29	11°	64.97	13°
IPC-13 - Unnecessary stock reduction	79.00	3°	94.34	7°	52.48	13°	75.57	6°

(Q4): There is a correlation on the influence of LSS between the pillars of TBL?

In order to assess whether the position of an impact on the ranking of influence in one of the three TBL pillars interferes with the positioning of the same impact on other pillars a nonparametric correlation analysis was performed using the SPEARMAN method, which seeks evaluate the relationship between two variables measured in ordinal form.

To perform this evaluation, the perceived ranking of influence of LSS impacts over each pillar of TBL we used, which was structured based on the frequency of reviews "With correlation" in relation to the total valid responses submitted by the 13 impacts assessed in the pillar.

In the relationship assessment between the perceived influence of the LSS impacts over Environmental pillar and Economic pillar, a strong positive correlation was identified, having been calculated a correlation of 0.7143. Due to the result it is possible to affirm that, in the opinion of experts, the greater the influence of LSS on Economic pillar, the greater its influence over Environmental pillar.

In 61.54% of the impacts (8 of 13) was possible to observe a variation of one or none position between the two rankings, which contributed strongly to the results found. The cycle time acceleration impact was identified as the one that showed greater variation in position between the two rankings, presenting the greatest influence over the Economic pillar, but with moderate influence over the Environmental pillar, reaching only the 8th position on the influence rank.

From the evaluation of the correlation between the perceived influence of LSS over Environmental and Social pillars, it was possible to identify a weak positive correlation between the variables, having been calculated a 0.1951 correlation for the relationship between the two pillars. The low correlation is mainly due to the significant position differences presented by some impacts, as in the case of the Increase employee satisfaction impact, which has a high influence over the Social pillar and low influence over the Environmental pillar. This same phenomenon is identified for the impact of unnecessary stock reduction, but in reverse, and for the Process variability reduction impact, but in lesser degree.

When the same evaluation was performed to compare the Social and Economic pillars, it was also identified a weak correlation between the pillars, but in a negative way, with a correlation of −0.0137. Having been identified major discrepancies on the rank position between the two pillars for the impacts: (i) Increase employee satisfaction, (ii) Cycle time acceleration, (iii) Increasing the quality of services and (iv) Unnecessary stock reduction (Table 7).

(Q5): There is a correlation between the influence of the impact on the TBL and its relevance in the literature?

In order to identify the correlation between relevance of the assessed impact for literature and its influence over the TBL we compared the impact position on the rank of influence over TBL with its position in the citation frequency ranking prepared by Freitas and Costa (2017). In order to perform this analysis, we used the SPEARMAN coefficient test with 95% confidence interval and developed the following null ($\mathbf{H_0}$) and alternatives ($\mathbf{H_a}$) hypotheses:

- $\mathbf{H_0}$: $rs = 0$
- $\mathbf{H_a}$: $rs \neq 0$

For the development of the test, is necessary to compare the result of this analysis with the reference values provided by Olds (1938). At a significance level of 5.00% (95.00% confidence interval) for a sample equal to 13, the reference value for rejection of the null hypothesis is 0.566. In the analysis performed, we could not rejected the $\mathbf{H_0}$ because the calculated value for SPEARMAN correlation (0.4698) was lower than the reference value (0.566), which indicates that there is no significant correlation between the influence of the impact and the volume of citations.

It is possible to observe that among the six impacts most cited by the authors, four also is present as the five more influential LSS impact over TBL, which are: (i) Increase product quality, (ii) Process variability reduction, (iii) Defect rate reduction e (iv) Waste reduction. The Increasing the quality of services impact, 3rd place in the ranking of influence on the TBL, does not appear among the six impacts most cited by the authors, reaching the 10th place in citations rank.

The (i) Costs reduction and (ii) Delivery time acceleration impacts, despite the large volume of its citations in scientific literature, stands by not have a high influence on organizational sustainability, having reached the same position, respectively 8 and 10, on the influence rank (Table 8).

(Q6): What is the most influential dimension to the TBL and its three pillars according to experts?

Through a frequency, analysis of the assessments "With correlation" received for each of the three TBL pillars distributed

Table 7
SPEARMAN test for correlation of the impact rank position between the three pillars.

Impact	En	Ec	So	En x Ec	En x So	Ec x So
	Environmental	Economic	Social	D^2	D^2	D^2
IPC-01 - Costs reduction	7°	4°	8°	9	1	16
IPC-02 - Increase product quality	5°	5°	5°	0	0	0
IPC-03 - Process variability reduction	4°	5°	10°	1	36	25
IPC-04 - Delivery time acceleration	8°	11°	7°	9	1	16
IPC-05 - Defect rate reduction	2°	1°	4°	1	4	9
IPC-06 - Waste reduction	1°	1°	3°	0	4	4
IPC-07 - Increase customer satisfaction	10°	10°	6°	0	16	16
IPC-08 - Cycle time acceleration	8°	1°	9°	49	1	64
IPC-09 - Increase employee satisfaction	12°	13°	2°	1	100	121
IPC-10 - Increasing the quality of services	6°	7°	1°	1	25	36
IPC-11 - Processes acceleration	11°	7°	12°	16	1	25
IPC-12 - Waiting time reduction	13°	12°	11°	1	4	1
IPC-13 - Unnecessary stock reduction	3°	7°	13°	16	100	36
	Σ			104	293	369
	SPEARMAN correlation			0,7143	0,1951	−0,0137

Table 8
SPEARMAN test for correlation between position on influence rank and position on citation rank.

Impact	Relevance in the literature		Influence over TBL		D^2
	% of citation	Rank	% WC responses	Rank	
IPC-01 - Costs reduction	21	1	73,47%	8	49
IPC-02 - Increase product quality	17	2	82,03%	4	4
IPC-03 - Process variability reduction	14	3	77,78%	5	4
IPC-04 - Delivery time acceleration	13	4	71,95%	10	36
IPC-05 - Defect rate reduction	13	4	87,42%	2	4
IPC-06 - Waste reduction	13	4	91,99%	1	9
IPC-07 - Increase customer satisfaction	10	7	74,28%	7	0
IPC-08 - Cycle time acceleration	10	7	73,27%	9	4
IPC-09 - Increase employee satisfaction	7	9	71,34%	11	4
IPC-10 - Increasing the quality of services	6	10	84,04%	3	49
IPC-11 - Processes acceleration	5	11	68,39%	12	1
IPC-12 - Waiting time reduction	5	11	64,97%	13	4
IPC-13 - Unnecessary stock reduction	5	11	75,57%	6	25
				Σ	193
			SPEARMAN correlation		0,4698

according to respective classification dimension of the LSS impacts, suggested by Freitas and Costa (2017). It was possible to observe that for the Environmental and Economic pillars the costs dimension had the greatest influence over them, with respectively 70.94% and 95.81% of "With correlation" reviews compared with the total of valid responses. It was observed that for Social pillar another dimension is introduced as the most influential over it, in this case the quality dimension appear as the most relevant, with 78.10% of valid responses (Table 9).

Through the frequency analysis, it was also possible to identify the dimension of LSS that has greater influence over organizational sustainability. The Quality dimension stands out when compared to the Costs dimension, as the one who has the greater influence when TBL is evaluated as a whole, having been identified a variation of 2.17% in the frequency presented by the two dimensions.

Despite the greatest relative frequency present by the Quality dimension, when compared with the other two dimensions it shows necessary to make a new hypothesis test, in the same way the conducted for the research question Q2, with the objective of evaluating the difference between proportions presented by each of the three dimensions for LTB as a whole.

The authors executed the proposed hypothesis test with a confidence interval of 95% using the 1.654 Z value and the 5% p-value as the rejection rules. We observed that the Quality and Cost dimensions have statistically the same proportion because, on the both comparative test (Quality x Cost and Cost x Quality) the null hypotheses could not be rejected, showing that the identified proportion of influence on the Costs dimension is equal to Quality dimension. The Satisfaction dimension remained as the one with lesser influence over TBL, even after the hypothesis test (Table 10).

5. Conclusion

The integration between Lean, Six Sigma and Sustainability has become, in recent years, a promising field of study, mainly due to the pressure experienced by the organizations regarding the fulfillment of sustainability criteria. Studies developed in recent years indicate that the LSS has the potential to be the system that will assist organizations in meeting sustainability requirements.

Despite the growing number of articles developed with a focus on the definition and application of conceptual models for this integration, few studies evaluate the present relationship between these three streams. Is relevant to highlight that we did not identify studies that seek to evaluate the impacts generated by LSS projects on the three pillars of TBL, evidencing the existence of a gap in literature. In addition, we did not identify studies in this field that use the survey method to capture the perception of the experts to carry out this evaluation, demonstrating the novelty brought by this study.

After the LSS experts assessment across the influence of the 13 selected impacts over organizational sustainability, considering the three pillars of TBL, it was possible to identify a high positive influence of LSS on organizational sustainability, with 76.81% of reviews "With correlation" in the total of valid responses.

According to the experts, LSS influence more intensely the Economic pillar of organizational sustainability, which reached

Table 9
Frequency distribution of perceived correlation between dimensions and TBL.

		Costs	Quality	Satisfaction
With correlation	Environmental	354	206	242
	Economic	503	302	488
	Social	355	239	372
	TBL	1212	747	1102
Valid responses	Environmental	499	297	494
	Economic	525	316	529
	Social	508	306	511
	TBL	1532	919	1534
% WC responses	Environmental	70.94%	69.36%	48.99%
	Economic	95.81%	95.57%	92.25%
	Social	69.88%	78.10%	72.80%
	TBL	79.11%	81.28%	71.84%

Table 10
Hypothesis testing for difference between two proportions with a confidence interval of 95%.

TBL	p1	n1	p2	n2	Standard deviation	Z	p-value
Quality x Cost	81,28%	919	79,11%	1.532	0,0165	1,3134	0,0945
Cost x Quality	79,11%	1.532	81,28%	919	0,0165	−1,3134	0,9055
Quality x Satisfaction	81,28%	1532	71,84%	1.534	0,0172	5,4770	0,0000
Cost x Satisfaction	79,11%	1534	71,84%	1.534	0,0155	4,6978	0,0000

94.38% of the "With correlation" reviews. By comparing the influence presented by the Economic pillar and the Social pillar of TBL, which reached the second place in the evaluation of influence (72.91%), we found a difference between the two frequencies of 21.47%, showing the existence of imbalance among the three pillars. With 62.17% of the evaluations, the Environmental pillar stands out as the least influenced by the LSS.

This research found that five impacts of LSS stand out as the most relevant to organizational sustainability: (i) Reduce waste, (ii) Reduce defect rate, (iii) Increasing the quality of service, (iv) Increasing product quality and (v) Reduce process variability. Among the five impacts most influential, the first two are related to Costs dimension and the other three are aligned to Quality dimension.

By SPEARMAN correlation, analysis has possible to identify a strong positive correlation between Economic and Environmental pillars, mainly due to the resource economy (materials, time, labor, work, etc.) generated from the use of the methodology and that has influence over the two pillars in a proportion form. Data analysis showed, however, indications that the Social pillar may experience worse performance with the implementation of LSS methodology the better its performance in the Economic pillar, mainly due to the potential pressures generated on employees and suppliers in the search of a better financial results.

Although it is possible to identify similarities between the impacts most cited by the authors and the impacts that have greater influence over organizational sustainability, it was possible to identify a moderate positive correlation between the citations ranking of impacts in the scientific literature and the ranking of influence over TBL (0.4698). The correlation analysis show that not every impact of LSS widely reported in the literature influences the organization holistically and that some significant LSS impact for the organizational sustainability are neglected by the literature.

Another important factor identified on this research was the importance of costs control for organizational sustainability. Despite the Quality dimension highlight as the one with greater influence over TBL, as shown by the frequency analysis, with 81.28% of the "With correlation" reviews in relation to the total collected responses, the hypothesis test for the difference between the dimensions proportions shows the Costs dimension has the same influence over TBL.

6. Research limitations, implications and directions for future researchs

The lack of real and long-term data of the impacts generated by real LSS projects on the indicators related to the three pillars of organizational sustainability are one of the limitations of this research. This study was carry out only with experts that had a personal profile on LinkedIn platform, being the expert sample, in this way, a limitation for this study. The low theoretical base related to the theme were also one limitations to this research, being necessary to work with the experts' perception.

This study expands the knowledge about the research topic by identifying the impacts of LSS projects that influence organizational sustainability and how much they influence each one of the three pillars of TBL. The methodology used in the set of studies performed is also a gain for this research field and for organizations, and can be easily replicated later by other authors.

The authors suggest the development of similar works using real data from LSS projects and works that seek to select LSS projects based on sustainability indicators or based on the most influential impacts previously identified by this study. Integrated models to measure the LSS based on the performance of the social, environmental and financial pillars ar also needed. In addition, it is necessary to direct the implantation and measurement models according to the specificities of different sectors. There is a need to studies that identify barriers and critical success factors to integrate these strategies into different processes and industries.

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