Full Length Research Paper

Evaluation of Lean Production System by using SAE J4000 standard: Case study in Brazilian and Spanish automotive component manufacturing organizations

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Accepted 18 October, 2012

The identification and measurement of best practices, in Lean Production implementation, followed by the evaluation of its usage level, in the organizations, are the adequate way through the elimination or minimization of waste. However, the lack of a coordinated and structured roadmap, in the Lean Production implementation, may result in poor and disappointing results. In that sense, it is important to identify the steps required to assess the stages of companies toward the Lean Production system. The purpose of this paper is to present a field research carried out within companies of the automotive sector, analyzing the level of Lean Production implementation. The data is collected from Brazilian and Spanish companies. The main groundings of Lean Production are presented, and the analysis of the Lean Production level is conducted by the application of the SAE J4000 standards. The obtained results were evaluated, considering a statistical analysis of the collected data, and, the main findings, can offer to the organizations some outstanding points, regarding the Lean Production best way of implementation.

Key words: Lean production assessment, SAE J4000, continuous improvement, operations management.

INTRODUCTION

Strategies, aiming at improving competitiveness as well as meeting adequately the attributes and the customers needs, have caused many enterprises to get their production systems adjusted to, by focusing on quality management and continuous improvement of products and processes. This adjustment, to the new market strategies, by the automobile industry, very often, has taken place by what is called Lean production system. Such a system was originated from the Toyota Production System, and has become a benchmark, in terms of efficiency, competitiveness, and struggle against wastes in the automobile industry.

Focusing on these facts and trends, in the automobile

industry scenery, it is needed to make an analysis of the important aspects that enable the enterprises to achieve excellence on the processes management, making a way for them to be competitive and profitable on their market segment.

Looking forward to contributing to this discussion, this article, presents field survey of data carried out within Brazilian and Spanish enterprises of the automotive sector, against the analysis on the degree of adherence to the Lean production system, obtained through evaluation by the SAE J4000 standard. The choosing of making a comparison between these two countries, is due to the fact that, despite Brazil being a continental country with knowledge and know-how on the manufacturing of vehicles based on the use of bio-fuel (e.g. Ethanol), the Spanish automobile industry has been a European benchmark whether on the output volume,

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exportation, or the consumption on the foreign market.

In order to do so, firstly, the theoretical main grounds of the Lean production system are presented, highlighting the techniques and tools of improvement programs. The analysis on the adherence level of a given enterprise, to the Lean production system, was performed by using the SAE J4000 standards, which have been described in this work.

The results obtained from the survey between Brazil and Spain, are presented into two parts: the comparing of the adherence level to the Lean production system between the two countries surveyed and a detailed statistical analysis of the data collected.

OVERVIEW OF THE MAIN LEAN PRODUCTION PRINCIPLES

The fundamentals developed by the Toyota Production System, which, later on, resulted in what is known nowadays as Lean Production, had as main philosophy the usage of identification and progressive minimization or elimination of waste sources, based on five paramount principles: the definition of value (i), from the client's point of view and needs, then determining the activities necessary for offering the product to the client with the lowest waste level through the definition of a value chain (ii). Then, the manufacturing of the product, using a continuous flow (iii) is sought, which is triggered only when the client places the order. That is, using a drawn production (iv). From these four principles and the usage of continuous improvement (*kaizen*) or a more radical one (*kaikaku*), the fifth fundamental principle, perfection (v), is sought in the system (Feld, 2000).

When analyzing the implementation of the Lean Production system in companies, it is noticed that it may happen using several techniques and methods, which must take place in a coordinated and structured way (Hunter, 2004; Rathilal and Singh, 2011). These methods and techniques must comply with the five fundamental principles of Lean Production system, mentioned in the previous paragraph. According to Feld (2000), these techniques may be grouped into five major categories, as described as follows:

- (i) Production flow – it engulfs techniques related to physical changes, product development procedures, and the definition of necessary standards. Some techniques and methods, related to this category, are: Value Stream Mapping (VSM); Process, products and/or services standardization; Takt Time definition; Cellular Layout, among others.
- (ii) Organizations and culture – grouped, in this level, are questions related to the individual, learning, communication, and shared values. Some techniques and methods, related to this category, are: teamwork, empowerment, definition of mission and values of the

organization, among others.

(iii) Process control – it approaches techniques related to the monitoring, control, stabilization, and improvement in the production process. Some techniques and methods, related to this category, are: SPC (Statistics Process Control), SMED (Single Minute Exchange of Die), 5S, TPM (Total Productive Maintenance), Mistake Proofing devices (*Poka Yoke*), among others.

(iv) Metrics – it engulfs techniques, which measure output, improvement, objectives, and reward measures for working teams and collaborators. Some types of metrics performed are: cycle time, inventory turn, aggregated value per worker, among others.

(v) Logistics – it mentions working rules, techniques and methods for planning and controlling internal and external material flows. Some techniques, related to this category, are: JIT (Just in time), *Kanban*, among others.

Together, such methods contributed to consolidate the Lean Production concepts, improving the performance in manufacturing operations (Grünberg, 2003, 2004), quality management and productivity (Rathilal and Singh, 2011).

It must be highlighted that, at the conception of the Lean Production system, no structure is considered as definite; the techniques and methods may be changed as technological and competitive needs arise. Anvari et al. (2011) proposed a dynamic model for a Lean Production roadmap, considering conditions of a high variability environment. In this work, the authors introduced some viewpoints and recommendations of the Lean Production implementation based in a literature review, pointing out that the system has to be implemented considering stages and steps.

However, the approach on systematically reducing waste (*muda*) on the value stream should be always considered in the Lean Production implementation (Taj and Berro, 2006).

SAE J4000 STANDARD

In August, 1999, the SAE (Society for Automotive Engineers) approved the SAE J4000 standard, called "Identification and measurement of best practice in implementation of lean operation". It was complemented in November, 1999, by SAE J4001, being called, then, "Implementation of lean operation user manual", which provides instructions for evaluating the usage level of organizations to the SAE J4000 standard (SAE, 1999a, 1999b).

The SAE J4000 standard, is the main document, and lists the criteria, through which the Lean Manufacture may be reached, always focusing on the elimination or minimization of waste. The main section of the standard is composed of 52 components, divided into 6 elements (ethics and organization; people and human resources; information system; client/supplier relationship and organization; product and product management; product

and process flow), which evaluate the implementation degree of principles related to lean operations, in a company, as explained as follows:

- Element 1 (Ethics and organization) – it analyzes the recognition and involvement of the board of directors and the top management with the Lean Production system, and, whether, the initiatives spread out by these, are being implemented, according to the organization's strategic planning. This planning, must be complemented along with a follow-up of the actions and results achieved, fostering the collaboration of all people involved, and awarding bonuses, when improvements and outstanding results, are accomplished by the corporation.
- Element 2 (Personnel and HR) – it checks the level of commitment of everyone in the organization to the success of the Lean Production System. This effort is assessed by the standard through a decision making democratization, higher autonomy, interdisciplinary team buildup, training, and guarantee of the resources for these team actions;
- Element 3 (Information System) – it makes sure whether the enterprise guarantees safe and well-structured access to the information needed, for the making of initiatives targeted to getting a Lean manufacturing. The information should make it easier to analyze situations under study, and, mainly, to enable the follow-up of the actions performance that have been made by the teams;
- Element 4 (Customer/Supplier and Organization Relationship) – it judges the relationship among supplier, company, and customer, assessing their engagement in areas, such as product development and the establishment of long lasting partnerships.
- Element 5 (Product and Product Management) – it takes into account the use of tools, connected to the product life cycle management, and the employment of multidisciplinary teams that hold specific skills for the development of new products, with the purpose of shortening the time, for the releasing of such products into the market, and the cost that comes along with this task;
- Element 6 (Product and Processes Flow) – this last category, encompasses the majority of the tools which, nowadays, are applied to the engineering fields, and seeks to guide the production flow to line up with the customers needs.

For evaluating the implementation degree, in each of these elements, statements are made by the components, which try to characterize relevant aspects of the Lean Production System implementation principles. Though each of the elements has a weight on the implementation, the relative importance that each of them has for the Lean Production System implementation success, is reflected by the number of components

related to each element (SAE, 1999a, 1999b). The J4000 standard defines a specific number of components, as well as an importance weight for each element, as shown on Table 1.

To each of the components, a measurement scale on the implementation level is associated, which guides the component usage scope comparison due to better practices applied in the industry (Calarge et al., 2008), as shown in Table 2.

Nonetheless, the standards SAE J4000 and J4001 do not define a way to measure the implementation level of practices in the lean management for a specific element or for a company as a whole. Inside this gap presented by the standard, Lucato et al. (2004) established a criterion, which allows evaluating the degree of adherence to the standard for both, the element and the company that is, taking into consideration the six elements. These formulas are shown as follows:

- (i) The implementation degree of a generic element “e” in the standard SAE J4000 (leaning degree for this element) may be obtained by dividing the sum of grades obtained in the evaluation of this element's components by the maximum possible grades for this evaluation:

$$g_e = \frac{(\sum \text{of obtained grades in the evaluation of components from element "e"})}{(\sum \text{of maximum possible grades for the components from element "e"})} \quad (1)$$

- (ii) The company's leaning degree (g) is given by dividing the sum of the elements' leaning degrees (g_e) by the number of elements considered in the comparison (p).

$$g = \frac{(\sum g_e)}{p} \quad (2)$$

A BRIEF CHARACTERIZATION OF BRAZIL AND SPAIN AUTOMAKERS

There are, in the world, just over one billion automobiles, knowing that in the year, 2008, according to, OICA (International Organization of Motor Vehicle Manufacturers), 70.5 million vehicles were manufactured; a rate, 4% higher, than the one of the previous year (OICA, 2009).

The automobile assemblers, in Brazil, are responsible for an average growth worth 11.25% a year, of the industrial GDP. Considering that the auto parts sector, despite suffering, at a higher degree, the ups and downs of the market, has achieved reasonable results, being held responsible in the year, 2008, for 5.5% of the overall Brazilian GDP. Data presented by both sectors' yearly reports, show that these sectors have invested a yearly average percentage worth, 4.0%, of their incomes, although such percentages have been decreasing over the last years. Another aspect, which demonstrates the

Table 1. Elements contained in the SAE J4000 Standard and their relative weights.

Element	Main theme	Number of components	%Weight
Element 1	Ethics and Organization	12	25
Element 2	People and Human Resources Management	13	25
Element 3	Information System	4	
Element 4	Client/Supplier Relation and Organization	4	25
Element 5	Product and Product Management	6	
Element 6	Product and Process Flow	13	25

Source: SAE (1999a).

Table 2. Measurement scale on the implementation level in comparison with better practices.

Level	Grade	Meaning
Level 0	0	The component is not implemented or there are fundamental inconsistencies in its implementation
Level 1	1	The component is implemented but there are still less significant inconsistencies in its implementation
Level 2	2	The component is satisfactorily implemented
Level 3	3	The component is satisfactorily implemented and has shown a continuous improvement for the last 12 months

Source: SAE (1999a).

importance of the automotive segment for the Brazilian economy, is the number of jobs that this sector provides, which means around 305,000 people, directly, namely 109,000, in the assemblers, and, 196,000, in the auto parts, which comprises a tally of 0.31% of the Economically Active Population (EAP), in the Brazilian industry. (ANFAVEA, 2009; SINDIPEÇAS, 2009; CNI, 2005; OICA, 2009).

Upon taking a look at data gathered from the Spanish automotive sector, it is noticed that, this sector, is also important for the Spanish economy, due to the prominent positive results of its commercial balance. The automobile sector, is taken, as being one of the pillars of the economy, together with the civil construction and tourism, holding more than, 6%, of the GDP, and for nearly one quarter of the overall exporting of the country, giving jobs to, 0.30%, of the active population, and handing over, significant amounts of taxes to the Spanish Revenue Service (ANFAC, 2008). This characteristic of the Spanish automotive sector is the result of a set of efforts and conducive circumstances, which took place during the 1980s, such as the European Community integration, and the development of the world economy.

When comparing the Spanish automobile industry to the Brazilian one, between the years, 1991 and 2000, it is noticed that, the Spanish vehicles fleet, practically, matched the Brazilian fleet, coming from 15 million to 21 million, while, the Brazilian one, moved from 14 to 20 million (ANFAC, 2008; ANFAVEA, 2008).

However, one of the differing factors of this reality is the global competitiveness capacity of the Spanish automobile industry, which has managed to export a far higher percentage than the Brazilian industry.

Table 3 shows some comparative data between the automobile industry of Brazil and Spain. It is possible verify that, besides putting more automobiles onto the foreign market, the Spanish automobile industry presents productivity and profitability higher than the Brazilian industry, once it has an inferior number of assembler plants installed in its territory, and employs a smaller number of workers.

DESIGN OF FIELD RESEARCH AND METHODOLOGY

The methodology used in this work is a field research, which studies the sample of a population through individual data collecting (not in group), employing as data collecting technique, questionnaires and personal interviews by phone, via mail and e-mail (Bachmann et al., 1999; Forza, 2002; Granello and Wheaton, 2004).

As field research may be descriptive, exploratory, or experimental, in this research, it was sought the quantitative checking of adherence level to the Lean production system, by the companies broadening and deepening the existing knowledge, so, characterizing it, as an exploratory field research. Similar studies, have been conducted, around the world, considering the relevance of the automotive industry and the implementation of Lean Production principles, in order to improve organizations performance, such as researches conducted in United Kingdom (Bhasin, 2011), South Africa (Rathilall and Sing, 2011), Malaysia (Salimi et al., 2012), and

Table 3. Comparative data between the Brazilian and the Spanish automobile industries for the year 2008 (ANFAVEA, 2009; ANFAC, 2008).

Characteristic	Brazil	Spain
Nº of assembling units installed	18	11
Nº of automobile industries installed	39	18
Passenger vehicles fleet	25.526.000	27.174.000
Output of passenger vehicles	3.216.000	1.943.049
Passenger vehicle exporting	369.285	1.655.092
% of total exporting over total output	11.5	82.6
Turnover (in million of U\$)	73.500	38.421
Investment (million of U\$)	2.913	1.673
% of the sector over GDP	2.7	3.5
Direct Jobs	109.848	67.624
% over number of jobs (direct-indirect) over active population	0.11	0.29
Productivity (passenger vehicle by worker)	29.2	28.73
Productivity (thousands of dollars by worker)	669	568
Number of inhabitants by vehicle	7.4	1.6

others countries.

Questionnaire

The content of the questionnaire, applied in this work, is based upon the instructions for evaluating the implementation degree of lean operations principles from the SAE J4000 standard document. The questionnaire was used to collect the information related to the six elements in SAE J400 standard, in order to measure the implementation level of lean management practices for a specific element, and for a company as a whole.

Pilot test

The step of the, pilot test, of the interview questionnaire, which consists of testing the research tooling on a small portion of the population, or sample, before its definitive implementation over a target public, so, avoiding comprehension, and understanding problems of the posed questions, was not necessary, due to the fact that, the questionnaire, is based upon an internationally recognized standard, SAE J4000, this phase, was taken, as already been accomplished.

Target population

The handling of the data collecting, in Brazil, took place with companies enlisted in the Brazilian Autoparts Manufacturers Association (SINDIPEÇAS), through data collected via e-mail. In Spain, the questionnaire was sent to a sampling of pre-selected companies through data collected via mail, and e-mail, by Spanish Car and Trucker Automakers Association (ANFAC). Other details, of this research handling, are listed in Table 4.

It is possible to note that the obtained returned rate, for the countries, were practically identical, noticing that the useful rate of the Spanish questionnaires was higher, though, due to the fact that the questionnaire had not had feedback, in blank, getting 100% efficiency of the obtained questionnaires (Table 4). The profile of the companies that replied presents itself in a similar way of characterizing them as big companies, holding a number of

employees ranging from 100 to 4,000.

Data analysis

The method for data analysis included descriptive and inferential statistics such as frequencies and means, confidence intervals, and hypothesis test, respectively. The degree of the Lean adherence level was calculated for the individual elements as well as for the company (taking into account the six elements at the same time).

A correlation study was also carried out in order to check the convergence and divergence, between the elements. The statistical package *R*[®] was used to process the data.

ANALYSIS AND DISCUSSION OF RESULTS

The analysis of results will be divided into two sections: the conduction of the analysis on the adherence level to the Lean production system, and, the description of the statistical analyses of the obtained data, in order to check the convergence and divergence among the elements.

Evaluation of the adherence level to the Lean production system

The calculation of the adherence level to the Lean production system was done, as shown in Figure 1 has proposed by Lucato et al. (2004), used in phases 3 and 4, respectively.

The calculation of the leaning degree for each element was done separately for each Brazilian and Spanish company. In Figure 2, the adherence level to the Lean production system in the respondent companies is presented.

The company leaning degree is obtained by using Formula 2. The average degree of leaning, for the Brazilian and Spanish companies, are shown in Figure 3.

Table 4. Comparative chart of the results related to the research method.

Characteristic	Brazil	Spain
Supplier companies of the automobile sector registered in syndicates in the country (Brazil/Sindipecas – Spain/ANFAC)	470	450
Samples sent	43	32
Questionnaires returned to addresser	9	7
Questionnaires answered	6	7
Questionnaires in blank	3	0
Questionnaires return rate	20.9%	21.8%
Rate of the useful returned questionnaires	13.9%	21.8%

Figure 1. Phases for evaluation of the adherence level to the lean production system. **Figure 2.** Brazilian and Spanish companies Adherence level to the lean production system.

Statistical analysis of data collected from Spanish and Brazilian companies

The statistical analysis of the results was done with the assistance of the statistical package *R*[®] (Bivand et al.,

2008), and divided into two sections: firstly, the handling of the adherence average level to the Lean production system for Brazilian and Spanish companies and, secondly, the description of a correlation study, between the obtained data, with the purpose of checking the

Figure 3. Brazilian and Spanish companies's leaning degrees.

convergence and divergence between the elements.

Due to the small sizing of the samples available, it was, first, performed the normality test of Shapiro-Wilk (Shapiro and Wilk, 1965) on the results, in regards to the leaning degree by element, and the overall leaning degree to Spaniard and Brazilian companies. This test calculates a W statistics, which tests whether an n size, randomized sample, comes from a normal distribution or not. Small values, for W , are evidences of the normality deviation. The results, for this test, are seen in Tables 5 and 6, for Spaniard and Brazilian companies, respectively.

The results enclosed in Tables 5 and 6 show that with the exception of the result for the element 4 in Table 5, all of the elements show the value "p-value" greater than 0.05, thus, indicating that with a 5% significance level, there will not be any rejection of the data normality hypothesis.

Upon checking the data normality, it was calculated the intervallic inference, with 80% confidence, for the average of implementation degree, of each element, present in the SAE J4000 standard, for both Brazilian and Spanish companies. The results showed in Tables 7 and 8 demonstrate that, even with a shortened confidence, the sampling error obtained is still very great, given the fact that, this result can, in a great extent, be attributed to the reduced number of observations done over the sample. Nevertheless, even with a small sample, it was possible to infer over the total leaning degree average, with 10% error, for the Spanish case, as it can be seen in the last column of Table 8.

Taking, for instance, the case of the Spanish companies, the results of Table 8, are graphically shown, in Figure 4, indicating the average value of the adherence level to the *Lean Production* System of the surveyed companies, as well as the corresponding confidence interval to the populational average. It can be noticed, with regards to the performed analysis, that:

(i) Element 1 (Ethics and Organization) indicates rooms

for improvement, mainly, in regards to what have to do with the board and the top management engagement. Such engagement must be spread throughout the organization and implemented alongside the organization's strategic planning.

(ii) Element 2 (Personnel and Human Resources) points out the engagement level of all collaborators in the organization. The concept, thereof, allows one to observe that the Spanish companies surveyed, have democratized the decision making with a higher degree of autonomy, provided by the interdisciplinary teams buildup.

(iii) Element 3 (Information System) highlights that the Spanish companies surveyed permit safe and structured access to the information needed, to make initiative, aimed at getting a Lean Manufacturing, which enables the follow-up of the development of the actions taken by the teams. It is worth noticing that, the confidence interval for the leaning average level with regards to that element holds an error less than 10%.

(iv) Element 4 (Customer/supplier and organization relationship) presents the highest level of improvements accomplished, making evident that the surveyed Spanish companies had as their priorities the partnership rapport among supplier, organization and customer, probably, to improve their engagement to the other areas (Product Development) or to establish long lasting partnerships. However, it cannot be inferred with assuredness, such a conclusion for the population, once the interval obtained for this element is the one which presents the lowest precision.

(v) Element 5 (Product and Product Management) posted the third, low evaluation rate, knowing that this component takes into consideration the use of tools, linked to the product's cycle life management, and utilization of multidisciplinary teams, holding specific skills to developing new products. Therefore, it can be observed that, the surveyed companies, still come across with some difficulties or have not reached the desired level, mainly, in regards to the time of the new products

Table 5. Normality test for the Spanish companies' data.

Element	1	2	3	4	5	6	Total
W	0.9561	0.9248	0.8902	0.7863	0.9272	0.9301	0.9778
p-value	0.7842	0.5075	0.2759	0.0299	0.5274	0.5518	0.9482

Table 6. Normality test for the Brazilian companies' data.

Element	1	2	3	4	5	6	Total
W	0.9429	0.8035	0.9499	0.9274	0.8773	0.8835	0.8028
p-value	0.6828	0.0632	0.7395	0.5601	0.2571	0.2854	0.06222

Table 7. Confidence intervals for the Brazilian companies' adherence level.

Element	1	2	3	4	5	6	Total
Sampling average	0.5085	0.5000	0.5278	0.4722	0.5185	0.5385	0.5139
Sampling standard deviation	0.2446	0.3068	0.2396	0.2919	0.2781	0.2427	0.2415
Sampling size	6	6	6	6	6	6	6
Significance level	0.2	0.2	0.2	0.2	0.2	0.2	0.2
t tabular	1.4759	1.4759	1.4759	1.4759	1.4759	1.4759	1.4759
Error	0.1474	0.1849	0.1444	0.1759	0.1676	0.1462	0.1455
Interval inferior limit	0.3612	0.3151	0.3834	0.2964	0.3509	0.3922	0.3684
Interval superior limit	0.6559	0.6849	0.6721	0.6481	0.6861	0.6847	0.6594

Table 8. Confidence intervals for the Spanish companies' adherence level.

Element	1	2	3	4	5	6	Total
Sampling average	0.5824	0.6270	0.6310	0.5119	0.6190	0.6886	0.6218
Sampling standard deviation	0.2494	0.2096	0.1791	0.3021	0.1936	0.1773	0.2016
Sampling size	7	7	7	7	7	7	7
Significance level	0.2	0.2	0.2	0.2	0.2	0.2	0.2
t tabular	1.4398	1.4398	1.4398	1.4398	1.4398	1.4398	1.4398
Error	0.1357	0.1141	0.0975	0.1644	0.1053	0.0965	0.1097
Interval inferior limit	0.4467	0.5129	0.5335	0.3475	0.5137	0.5922	0.5121
Interval superior limit	0.7181	0.7411	0.7284	0.6763	0.7244	0.7851	0.7315

release to the market, as well as the costs that go with it. (vi) Element 6 (Product and processes flow) is the one that got the best performance among the evaluated elements, indicating that, mainly, the Spaniard companies are applying management methods and approaches, targeted at driving the production flow to lining up with the customer's needs.

Purposing at comparing the obtained values for the Brazilian and Spaniard companies, it was carried out a *t* test, to the observations done, over the leaning level average of each element, as well as for the total leaning. The objective was to find out whether there was any real difference between the two groups (Spain and Brazil), or, whether, the observed variation, could have occurred

randomly. Two sided hypothesis tests were done using the distribution *t*, at 5% significance, to check if there were any, significant differences, between the adherence level averages to the Lean Production system for Spanish and Brazilian companies. In this case, the null H_0 hypotheses of equality, were tested among the average values of the adherence levels by element, and total as well. The results are shown in Table 10. The preliminary results of the equality tests between the variance of the population at 5% significance needed to apply the *t* test, for the differences between the averages are presented in Table 9.

The values shown in Table 9, that neither to the adherence level for each element, nor for the leaning level, the equality null hypothesis of the variance, at 5%

Figure 4. Adherence level average to lean production system and confidence interval to Spanish companies' populational average.

Table 9. Hypothesis' tests to the total and by element variance adherence levels.

Element	Sampling variance		F-test statistics	Inferior critical value	Superior critical value	p-value	Result for H ₀
	(Brazil)	(Spain)					
1	598.083	622.619	1.041			0.985	
2	940.310	434.901	0.462			0.375	
3	573.038	328.901	0.574			0.517	
4	852.594	911.571	1.069	0.167	6.980	0.962	Do Not Reject
5	722.783	377.476	0.488			0.408	
6	590.095	319.810	0.542			0.477	
Total	583.050	406.568	0.697			0.667	

Table 10. Hypothesis test to average values of the adherence levels.

Element	Sampling average		t-Test statistics	Two-sided critical value	p-value	Result for H ₀
	(Brazil)	(Spain)				
1	0.5085	0.5824	0.5372		0.5927	
2	0.5000	0.6270	0.8834		0.3949	
3	0.5278	0.6310	0.9001		0.3874	
4	0.4722	0.5119	0.2459	2.2010	0.8103	Do Not Reject
5	0.5185	0.6190	0.7620		0.4621	
6	0.5385	0.6886	1.2821		0.2262	
Total	0.5139	0.6218	0.8795		0.3879	

Table 11. Correlation coefficient and p-values of the collected data from Spanish companies.

Element		2	3	4	5	6
1	Correlation	0.9800	0.7517	0.9248	0.9871	0.8017
	p-value	0.0001	0.0513	0.0028	0.0001	0.0301
2	Correlation		0.8058	0.8930	0.9982	0.7931
	p-value		0.0278	0.0068	2.5e-7	0.0333
3	Correlation			0.5885	0.8028	0.4426
	p-value			0.1645	0.0297	0.3200
4	Correlation				0.8899	0.7773
	p-value				0.0073	0.0397
5	Correlation					0.7924
	p-value					0.0336

Table 12. Correlation coefficient and p-values of the collected data from Brazilian companies.

Element		2	3	4	5	6
1	Correlation	0.6887	0.7613	0.8185	0.7682	0.8324
	p-value	0.1303	0.0787	0.0464	0.0744	0.0398
2	Correlation		0.5349	0.7756	0.7843	0.8604
	p-value		0.2741	0.0699	0.0648	0.0279
3	Correlation			0.5104	0.8940	0.6680
	p-value			0.3009	0.0162	0.1470
4	Correlation				0.7267	0.9656
	p-value				0.1018	0.0017
5	Correlation					0.8731
	p-value					0.0231

significance level, can be rejected. This conclusion can be obtained by checking that, the F statistics value, is always contained within the critical limits, inferior and superior, or even so, by checking that the p-value is lower than α for all the cases tested. Thus, it can be concluded that the variances between the populations, two by two, are equal, and so, to use the suitable test *t* for this situation (Montgomery, 2001).

It follows, from the results of Table 10 that, either evaluating the p-value, which is higher than 0.05 for all the cases, or noticing that the test's statistical value do not belong to the critical region, it is concluded that at 5% significance, there is not any difference between the two groups assessed. This means that statistically there is no significant difference between the results obtained from the Brazilian and Spaniard companies regarding the adherence levels to the Lean production system.

In addition to this, a correlation analysis, based on the sampling concept, using the model of Karl Pearson for simple correlation calculation, was performed (Johnson and Wichern, 1997).

Tables 11 and 12 shows the correlation coefficients between variable analyses and their corresponding p-values.

It is possible to notice that all of the presented correlation coefficients, in Tables 11 and 12, output positive values, meaning that the correlation between the even elements, apart from being null is straight that is when one element increases (or decreases) its evaluation, then the leaning degree also increases (or decreases) indicating that all the even elements have straight relation of proportionality.

Another related observation is the fact that the greater the linear correlation coefficient, the lesser the obtained

p-value, which implies there is a higher correlation confidence.

Given the fact that, in general, a strong correlation level is associated to coefficients superior to 0.70, the results indicate that the decision making for a given element, will have influence on the other elements, either in a positive or negative way, once the coefficients obtained from the data analysis, are over this value for 24 out of the 30 possible associations of these elements.

For the Spanish companies surveyed, the element 3, is the one which shows the lowest correlation coefficients, concerning the elements 4 and 6. This aspect demonstrates that decisions made for the element 3 had influence in a small degree over the other related elements. Nevertheless, the decisions made which interfered directly with the element 1, interfered on a strong manner the elements 2, 4, and 5, due to the fact that they presented a higher correlation coefficient. A similar behavior can be noticed with regards to the Brazilian companies surveyed.

Conclusions

This article was aimed at analyzing how companies are conducting the Lean production system in the automotive sector of Brazil and Spain. The research, made it possible, on a preliminary manner, to evaluate the implementation degree of Lean Production elements of such companies, taking into account the SAE J4000 Standard series. The data analysis enables to point out that, despite the companies had been researched in Brazil and Spain, they present very similar structural operational conditions, and, the surveyed Spanish companies, held a higher leanness degree, when compared to the surveyed Brazilian ones. The statistical and correlation analyses, also made a way to identifying some outstanding points, mainly, regarding the obtained correlation coefficients, which output that the correlation between the elements is straight, that is, when one element increases (or decreases) its evaluation, the leaning degree increases (or decreases) as well, indicating that all of the even elements have direct proportionality relationship. Similarly, considering the surveyed Brazilian and Spanish companies, the most impacting elements regarding the *Lean Production* practices implementation, are the element 1 (Ethics and Organization), which impact, principally, the element 2 (Personnel and HR), element 4 (Customer/Supplier and Organization Rapport) and element 5 (Product and Product Management), making evident the importance of the aspects related to organizational culture, ethical awareness, and participative top management, as critical success factors on *Lean Production* implementation.

ACKNOWLEDGMENT

Authors would like to thank Nove de Julho University-

Uninove for the financial support.

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