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LEAN PRODUCTION IN CONTINUOUS PROCESSES: A SURVEY OF BRAZILIAN MANUFACTURERS OF ELECTRIC CONDUCTORS

José Lourenço Júnior[1], Messias Borges Silva[2]

Abstract

This paper aims to present information relating to the levels of Lean Production practice in continuous manufacturing, particularly among manufacturers of electric conductors. It proposes to identify the motivations that led these companies to search for the model and to understand the role of tools and techniques employed in this manufacturing environment so different from the automotive industries where the concept originated. This article presents the results of a descriptive exploratory survey with manufacturers of electric conductors (electrical distribution and transmission wire and cables) in the State of Sao Paulo, Brazil. The results suggest that the adoption in the electric conductor industries still requires a more significant evolution both in the dissemination of ideas and in the customization of the applicable tools. On the other hand, the paper provides empirical insights and contributes to fulfilling an identified need to study Lean Production in continuous manufacturing.

Keywords: Lean Production; Continuous Processes, Electric Conductors

1. Introduction

At the end of the Second World War, the Japanese began the production of vehicles and they immediately were confronted with restrictions of their limited internal markets, which rendered unviable the then-established concepts of mass production used with success by Westerners. The Japanese companies of that time could not fire employees and the economy of a country devastated by war did not have the resources to make the high investments necessary for the implementation of mass production. Under this context of difficulties and limitations, the Japanese automobile company the Toyota Motor Company devised and implemented new methods of production and administration, baptized as the Toyota System of Production. The basic principles had been formulated by Sakichi Toyoda (founder

[1] Centro Universitário Salesianos de São Paulo – UNISAL-Lorena
[2] Universidade Estadual Paulista – UNESP-Guaratinguetá

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of the Toyota Group) and his son Kiichiro Toyoda in the 1920's and 1930's. However, these concepts were only operationalized and associated among one another by Taiichi Ohno at the end of the 1940's (Womack, 1996). Such methods made possible the simultaneous use of several models in small scale, improving quality and reducing costs. The key word thus became "muda" (pronounced *mudá* in Japanese), which in synthesis represented all which did not add value in the eyes of the customer, which should then, as a result, be eliminated.

The rest of the story is the well-known Japanese ascent and leadership in the automobile market and the establishment of that country as a world economic power by the 1970's (Womack et al, 2007). In the first quarter of 2007, Toyota would surpass General Motors as the world leader in vehicle sales. The difficulty of the American automobile manufacturers in staying in front of their Japanese competitors is partly attributable to the many failures in their manufacturing systems and management principles. For example, the philosophies of these two groups of companies vary considerably, particularly with respect to relations with the supply chain. The Japanese assemblers manage their suppliers as an extension of the company itself, working closely with them to reduce their costs through development of their abilities. Meanwhile, American companies are notoriously well-known for demanding unilateral cost reductions on the part of the supplier, using adversarial and potentially unethical methods which, in the short term, may well yield positive effects on their results. (Hill et al, 2009).

But the revolutionary system of production started in Toyota would only become popularized to western eyes in 1990, with the publication of the book "The Machine That Changed the World" by Womack et al, as a result of a study conducted by *The International Motor Vehicle Program*, at MIT – *Massachusetts Institute of Technology* (Holweg, 2007). In the book, the system received the name in English of "*Lean Manufacturing*", in the sense of "without fat, without superfluities and waste" that is without "muda" (Womack et al, 2007). According to Cusumano (1989), Ohno

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(1988) and Womack et al (2007) the principal characteristics of the system of Lean Manufacturing are:

a) The production line is planned from the real demand of the market, and no longer by the forecasts of the market made by estimates or planning. The production is thus "pulled" by demand instead of being "pushed" by planning.
b) The manufacturing cycle is always being reduced in a process of continuous improvement, which demands great flexibility and minimum preparation and change times.
c) Automatic quality control.
d) Reduced and tending-to-zero inventory.
e) Strengthening of the link between employer and employee based on a climate of mutual confidence and dependence.;
f) Relationship with suppliers based on a long-term partnership.

The objective of the system is, according to Ohno (1988), the elimination of waste and unnecessary elements with the goal of reducing costs. The basic idea is to produce only that which is necessary, at the necessary moment and in the required quantity. To Shinohara (1988), the philosophy of this system is the search for a technology of production that uses the smallest quantity of equipment and labor to produce goods without defects in the least time possible, with the minimum of intermediate units, understanding as waste any other element that does not contribute to the quality, price or time period required by the customer. The goal is to eliminate all waste through the concentrated efforts of management, research and development, production, distribution and all of the departments of the company. And for Womack et al (2007), the organizational characteristics of a lean factory are those of conferring the maximum number of functions and responsibilities to all the workers that add value to the product in the production line, and the adoption of a system of defect handling applied immediately to each problem when it is identified.

2. Limits of Lean Production

Womack and Jones (1996) go further by defining the concept of “Lean Thinking”. The essential point is value, as the final customer recognizes it. This is significant when expressed in terms of a specific product (a good or a service and, many times, both simultaneously) that attends to the needs of the customer at a specific price at a specific moment. This results in the “lean company” as an extension of Lean Manufacturing. However, the lean company goes much further by focusing, beyond the traditional limits, on its employees, partners and suppliers to the end of adding value to the customer. The lean company seeks the alignment and the coordination of the process of creating value for a finished product or service all along the business flow. All of the processes are continually examined in relation to the definition of value as seen by the customer, and the waste and the activities without added value are methodically eliminated. In this sense, the authors Bhasin and Burcher (2006) converge to the idea that the lean concept should be seen as a philosophy, an understanding shared by Ohno (1988) upon confirming that the Toyota System of Production is not only a system of manufacturing, but rather a global system of administration.

Despite the great repercussion of the concepts of Lean Production in contemporary companies, a large part of the success stories comes from the automotive industry, especially in assembly line arrangements. They are characterized, therefore, by elevated volumes of a relatively small variety of products. Other manufacturing companies of discrete products, such as the electronics industry followed the steps of the automotive industry through the application of lean concepts. The majority of these companies also were successful in the adoption of lean thinking. The literature on Lean Production seems to still not have a key performance measure for the implementation of the concepts considering many types of industries (Lee and Allwood, 2003; Pool et at, 2011). It is clear that Lean Production as a concept evolved, and will continue to evolve as time passes. Consequently, as the phases of this evolution occur, different reviews are raised. The article by Hines et al. (2004) is an interesting review concerning these phases and of the gaps of scientific knowledge regarding the lean concept. Table 1 presents a general vision of these gaps and their principal critics.

Table 1 – The main gaps and criticisms of lean thinking

	1980-1990	1990-mid 1990	Mid 1990-1999	2000 +
Key gaps	Outside shop-floor Inter-company aspects Systemic thinking Auto assembly only	Mainly auto Human resources, exploitation of workers Supply chain aspects System dynamics aspects	Coping with variability Integration of processes Inter-company relationships Still mainly auto Integrating industries	Global aspects Understanding customer value Low volume industries Strategic integration
Main critics	Carlisle and Parker (1989) / Fucini and Fucini (1990)	Williams et al (1992) / Garrahan and Stewart (1992) / Rineheart et al (1993)	Davidow and Malone (1992) / Cusumano (1994) Goldman et al (1999) / Harrison et al (1999) Suri (1999) / Schonberger and Knod (1997)	Bateman (2000) / Christopher and Towill (2001) / Van Hoek et al (2001)

Source: Hines (2004)

There are authors who have argued that the lean approach cannot have a universal applicability for all organizations. The criticism to the lean way of thinking can be generally divided into those who concentrate principally on operational questions and those that cite the limits imposed by the necessity of creating a commercial and operational synergy before this approach can be adopted by the purchasers and suppliers along the supply chain (Cox and Chicksand, 2005).

Cox and Chicksand (2005) maintain that there are two principal operational criticisms made regarding lean production. The first is associated with the *Agile Manufacturing* School. Under this way of thinking the lean approach would work better if there were high volumes and relatively predictable demands with assured supply. However, with low volumes and unstable supply chains, where the requirements of the customer are often unpredictable it becomes difficult to control the innovations and the productive capacities of the suppliers, and a more agile and sensitive approach based on innovation would be operationally more convenient. A

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second operational criticism of lean approach is that is does not have universal applicability as a production system. The argument is made that among specialty and specialist component manufacturers in the automotive sector, batch and craft-based systems persist. Along the same lines, they argue that there is no evidence that all production systems are moving in the direction of Lean Production in all types of industries, and that this results because ‘just-in-time’ cannot be maintained without the leveling of production being possible internally within the organization and with the external suppliers of the supply chain (Cooney, 2002; Cox and Chicksand, 2005).

On the other hand, from a strategic and commercial perspective the universal applicability of the lean concept is also questioned. Some authors have commented on the difficulty of reaching ‘win-win’ results when there is a dominant buyer in the supply chain. The work of Cox and Chicksand examines, from this perspective, the adoption of management by lean thinking in the supply chain of fresh and frozen beef in the United Kingdom. They find that lean concepts may be helpful for some participants, but it is not an absolute recipe for sustainable competitive advantage for many other participants in the same supply chain. As a result, the authors propose investigating whether this is a general rule for food and agricultural chains of supply or it is limited to the supply chain for beef in the United Kingdom (Cox and Chicksand, 2005).

There are not many studies that discuss the limits of the applicability of the concepts of Lean Production. Alford et al. (2000) present the problem that a greater variety of products resulting from customization, even within the automotive industry, would imply higher costs and complexity in manufacturing. The authors discuss how it is unknown whether a system of manufacturing based on Lean Production would respond to this challenge. They conclude that an effective approach should be developed which would support decisions in taking customization initiatives and the resulting increase in variety in the interest of preventing elevated costs and complexity. Another similar opinion is offered by Cusumano (1994), principally

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concerning the question associated with the elevated diversification of products, when discussing the limits and restrictions in the applicability of the concept of Lean Production.

Jina et al (1997) identify as one of the most important programs of Lean Production outside of the automotive industry, in the United States, an initiative of the U.S. Air Force, of MIT and of 25 companies. As a result of this program, examples of the application of lean concepts in the manufacture of low volume and high variety products, in this case airplanes were reported. Companies such as McDonnell Douglas and Lockheed described the application of lean principles from design until the manufacturing of the product. In the same article, the authors approach questions and propositions applied to the manufacture of low volume and high variety, characterizing it as:

a) From a high variety of products, as they can become personalized, in spite of the total volumes remaining low;
b) *Make-to-order* policies with delivery dates and times guaranteed;
c) Varying levels of vertical integration. Many organizations compete based on the originality and variety of the product, and, for greater control, maintain a high level of vertical integration. However, at the other extreme are companies that cannot maintain internal control due to the technological complexity of the business, that cannot afford high investment levels and consequently outsource heavily. Companies having high variety and low volume can have products in their portfolio that include these two extremes of vertical integration.
d) Having to satisfy the necessities of different segments of clients, both the specialized user of low volumes of finished product as well as those who buy reasonably standardized kits and replacement parts in slightly higher volumes.

The authors use the expression “turbulence” to describe the behavior that, as a result of variability and of the uncertainty of orders, impacts the production system in causing unpredictability and operation below the optimal point. They admit that companies with high variety and low volume confront more severe turbulence that those where typically Lean Production has been exhaustively studied. And they identify four types of causal factors of turbulence: (1) changes in planning which, frequently, make the delivery date earlier and reduce the available time;, (2) significant differences in product mix between one period and another (3) the volume itself, which, like the product mix, may change, and (4) the product design, where the impact and the frequency of changes of products can interfere with the expectations of manufacturing time. The authors conclude that the lean formula is directly applicable only to a small fraction of industries. The majority of companies should carefully judge which practices may be immediately utilized and which must be adapted to handle special circumstances. They present the barriers that many high variety, low volume organizations confront as impediments to lean principles in their operations and they demonstrate how these principles may be adapted to attend to the demands and challenges that confront these businesses (Jina et al.,1997).

Hines at al. (2004) emphasizes the criticism with respect to the capacity of Lean Production systems and the difficulty of supply chains in dealing with variety. For practical purposes the goal of adding value to the client the lean approach seeks forms of dealing with variability, using the assets more efficiently than traditional systems. The tool *Heijunka* (leveling used in the Toyota Production System) was developed to do this. However, in the case of demand variability, the approach in the sense of evening out or controlling demand, comes from environments of relatively stable demands, such as the supply chains of the automotive sector.

The question with respect to the response of Lean Production to a greater variety of products is justified by the essence of the concepts. According to Hopp and Spearman (2004) the key to the efficacy of pull systems is that they explicitly limit the quantity of work-in-process that can be present in a given manufacturing route. On the other hand, Takt Time control is a concept predominantly used in the final assembly that establishes a fixed rhythm of production that is equal to the demand rate of the client. It may be calculated dividing the production time available by the client demand (that is, the current list of orders). The restrictions imposed by these principles of Lean Production simplify production control and reduce variability in the system. The 'pull' system and the Takt Time are lean principles and have been applied principally in high volume environments in which the material is moved along a limited number of identifiable routes (Bokhorst and Slomp, 2010).

Jos Bokhorst et al. (Slomp et al., 2009; Bokhorst and Slomp, 2010) describe the application of the elements of Lean Production in a typical *make-to-order* and *job shop* industrial organization; a manufacturer of a great variety of parts in small lots. It deals with Eaton Electric General Supplies, suppliers of copper bars for Holec, a business unit of the electric sector of the Eaton Group, in Hengelo, Holland. In this business, Eaton develops, produces and commercializes equipment for the control of electrical energy for industrial, commercial and residential markets. Before the adoption of the elements of Lean Production, the unit had an enormous quantity of work-in-process and a great variability of delivery periods. Employees did not understand clearly the next task to be completed and, many times, preferred staying on their favorite machines, even though 20% of the work stations had urgent orders. This resulted in uncertain and unreliable lead times. With the support of researchers of the University of Groningen, three lean concepts were identified that would be applied to the production of copper bars: CONWIP (constant work in process), FIFO sequencing and Takt Time. CONWIP has as its purpose restricting intermediate (in process) stock to contribute to the objective of a reduced average transfer time between work stations. FIFO assures focus on the oldest orders in the system, thus reducing the variability in processing times. Takt Time promotes a regular flow of processing according to the demand of the customer, so that, upon introducing it the lead times becomes fixed, that is, the CONWIP product by Takt Time becomes and remains constant. The development of the system CONWIP/FIFO/Takt Time was supported by a simulation process through the software Tecnomatix Plant Simulation 7.6, which contributed to the acceptance of

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the system by the managers of the factory. In sum, the authors relate that insights developed in the simulation were incorporated in practice with favorable results and conclude that the wider application in industrial environments analogous to that of the study is likely.

3. Research Method

The research to which the present work refers was performed with manufacturers of electrical conductors for the transmission and distribution of energy in São Paulo state (Brazil). These, by design, belong to a distinct type of environment of discrete production. Table 2 presents a comparison between the typical industries in the automotive sector and the manufacturers of electrical conductors.

The manufacture of conductors can include the processes of melting of metals, lamination, wiredrawing, weaving, extrusion of thermoplastics and thermosetting plastics, cording and joining conductors. They are obtained from many different combinations of diameters of wires, in different quantities, with different cording directions, manufactured from different conducting materials (for example, copper or aluminum), covered and isolated with varied materials (different polymers or rubbers), woven and jointed in a multiplicity of possible physical constitutions and even with different constructive components. Hence, this is the primary characteristic of the industrial environment being researched: the great number of distinct products determined by the variety of combinations that may be assembled. Another relevant and fundamental characteristic is an aspect of continuous processes, in which discrete products do not exist during the manufacturing flow, but only at the end when packaged. In the process of manufacturing of electrical conductors a discrete unit of product can be defined only after the entire length of the conductor has been added to the spool or roll.

Table 2: Peculiarities of the automotive sector and manufacturers of electric conductors

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	Automotive Sector Industries	Conductor Manufacturing Industries
Products and Production	Determined by demand forecast. Reduced variety of products. Hundreds or thousands of items produced per period.	Make-to-Order. In spite of belonging to the same "families of products" there is an enormous variety of specific types. Units or dozens of items produced per period.
Numbers of raw materials	Tens or hundreds.	Units.
Planning and production control	Complexity in the planning of the production resources such as equipment, material and labor.	Complexity in the sequencing of the production orders. Shared utilization of the same resources for varied products. Fluctuating bottlenecks.
Quantity of finished products	Normally hundreds of thousands of unit parts manufactured in minutes or hours.	Units or dozens of discrete units (spools, rolls or bobbins) manufactured in hours or days.
Quality Control	Emphasis on Statistical Quality Control. Possibility of destructive tests by sample.	Emphasis on control and standardization of the productive process. Difficulty in the use of destructive tests, except in the extremities of the conductors.
Supply chain	Several suppliers normally located close to the factory.	Few suppliers and often far away. Frequently monopolists or oligopolists.
Physical arrangement	Assembly line, production cells.	Hybrid: functional and in-line.

The research had as its principal purpose obtaining preliminary information concerning the current levels of implementation of the concept of Lean Manufacturing among the manufacturers of electrical conductors operating in São Paulo state, Brazil. A secondary objective was the identification of the motivations for which companies seek the concepts of Lean Production and then to evaluate, among the roll of tools and techniques of Lean Production, which are used more and which are used less. Given that these are the objectives, combined with the added intention of understanding the use of the concept and its tools in the environment being studied, still in an incipient form, the survey performed is of an exploratory, descriptive character. According to Miguel and Ho (2010) and Forza (2002), a survey of exploratory character is appropriate when the intention is to acquire an initial view of the subject and understand it better, and the descriptive

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survey is adequate to describe how a particular phenomenon occurs in a population and its relevance.

3.1 Research Instrument

The instrument selected for data collection was an electronic questionnaire which could be read and responded to without the interference of the researcher. For the collection and storage of data, the questionnaire was implemented so as to be accessed and filled out via the Internet, through an open-source application known as LimeSurvey® (http://www.limesurvey.org), with a database MySQL™ and the Apache server, both also open-source The on-line form used generates statistics and permits the exportation of data in Microsoft Excel format. The type of questionnaire adopted is structured and undisguised, in which the questions are predominantly closed and the objective of the research is known by the respondent (Miguel and Ho, 2010). A pre-test of the questionnaire was performed by having it filled out by respondents who both were both familiar and unfamiliar with the subject, all of them industrial executives. There were a total of twelve questions asked in the following order.

a) Four initial closed questions referred to information about the company and of the respondent, in order to determine the scale of the company, the origin of its capital and the hierarchical position of the respondent;
b) A two-part question concerning whether the company has decided to apply the concept of Lean Manufacturing, whether it is being implemented, or whether its techniques and tools are already in use, even if only partially;
c) A closed set of questions in matrix format, in which follow-up questions depend on the answer "yes" to the corresponding main question. Respondents were asked to evaluate how much each of 17 possible motivating factors contributed to the implementation of the concept. In this question the Likert scale was adopted as the measure of intensity, with five possible alternatives;

d) A closed question about how advanced the implementation of the concept was within the company;
e) A set of closed questions in matrix format, in which the respondent was asked how much each of five assertions was identified with the perception of the concept of Lean Production within their company. Here the Likert scale was also used with five alternatives;
f) A set of two closed questions in matrix format concerning the sixteen tools and techniques of Lean Production with respect to their applicability and stage of application through scales with four and three alternatives, respectively;
g) An open question about what other tool or technique not listed among the sixteen prior questions would have been in implementation or had been implemented in their company;
h) A final question, closed and in matrix format, where the respondent should indicate, for each one of seven listed potential benefits, the expectation of obtaining it or whether the benefit has already been obtained, also through a Likert intensity scale with five alternatives.

The questionnaire, accessed through a link, included in its header the sponsoring university (UNESP) and an explanation that the survey was part of a doctoral program of the author, citing explicitly the author's name and that of the orienting professor. Next, participants were thanked in advance and a declaration of confidentiality clarified that respondents and companies would not be identified, and that the code sent for the exclusive purpose of permitting access upon being used would generate an untraceable record in a separate database that could not be linked to the respondent.

3.2 Population, Sampling and Data Collection

The selection of the sample was done in a deliberate manner, with the intent of selecting companies that best fit the profile of companies that manufacture conductors in the state of São Paulo, and, for that matter, of the entire country of Brazil, given the dominance of São Paulo state in hosting such manufacturers. As such, the research occurred among and with the support of the members of SINDICEL (Syndicate of the Electric Conductors, Drawing and Lamination of Non Iron Metals of the State of São Paulo). It is should be admitted that among the manufacturers operating in the state, the ones associated with the Syndicate have effective participation in sectorial committees and union negotiations and are the ones with larger scale. Forty eight companies associated with the Syndicate received the request for participation in the research. Given the deliberate selection of companies within this sector, we have no intention of extrapolating the results, but rather only wish to pursue the purpose of offering basic information about the segment.

The invitation for participation in the research was done through individual emails from the Executive Director of SINDICEL (the highest executive in the organization) addressed specifically to the likewise highest executive of each associated company. The content of the emails consisted of a greeting (in many cases personalized) with a clarification of the academic purposes of the research, of the seriousness of the parties involved and of the terms of confidentiality, seeking to assure the respondent with respect to the brevity and practicality of the on-line form. It left up to the recipient if the responses would be given by the recipient himself or forwarded to another professional within the company. With the purpose of trying to achieve a higher rate of return, the same emails were resent to those who had not responded within the first 30 days. And finally, 45 days after the first email, the author himself sent emails to those responsible for the quality area within the company (this time without specifying by name the recipient), reiterating the request of participation. It is worth emphasizing that the on-line tool used in this research permits response control through the individual codes assigned to each company, which facilitated the attempts to solicit response and improve participation, and even prevented more than one response from the same company. The on-line form was available on the internet between the months of September and November of 2009.

The return rate remained at 22.9% (with eleven companies responding), obtained from the responses to the first email, that is, the companies that did not respond to the invitation sent initially to the top executive likewise did not respond to the resend nor to the email directed to the person responsible for quality. According to Forza (2002) in surveys of exploratory character there is no minimum forecast for the return rate and, on the other hand, for descriptive surveys, the rate should be greater than 50% of the population being investigated. Miguel and Ho (2010) emphasizes that, in spite of an acceptance rate of 20% being common in the literature, such values limit the validity and the capacity of generalization of the results. Compared to works using similar research methods such as that of Pinto et al (2006) and Antonelli and Santos (2009), with return rates of 19.8% and 18.3 % respectively, the rate is considered satisfactory although it demands caution with regard to generalizations and absolute validity.

4. Results and Discussions

4.1 Characterization of the companies and of the respondents

With respect to the origin of capital, 36.4% responded as foreign. The global market of electric conductors has in the last few years gone through processes of mergers and acquisitions, reducing significantly the number of players. The companies with foreign capital that responded to the questionnaire represent all of the principal world manufacturers with presence in Brazil. To classify the companies with respect to size, the criteria of BNDES (Brazilian National Bank of Economic and Social Development) concerning gross operational revenue was used and that of SEBRAE (Brazilian Service in Support of Small Businesses) with respect to the number of employees. The majority, 72.7%, responded having an annual billing of more than 60 million reais (about €26 milion), with 63.6% stating that they have more than 400 employees. The collected data confirmed that the selection in the sample was adequate for what was planned in the research. And finally of the

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question set, 63.6% of the respondents were managers, 27.2% were at the President or Director level and 9.1% were supervisors.

4.2 Regarding the implementation of Lean Production and its techniques and tools

Of the participating companies, 45.5% responded that they had already implemented, were in the process of implementing, or had decided to implement the concepts of Lean Production (or its techniques and tools), even if only partially. Of these, the four foreign companies contributed 80% of that percent (four of the five companies that responded “yes”). However, although by a small difference, the majority of the companies did not decide in favor of the adoption of the concepts, and all of these were Brazilian companies.

Table 3 – Reasons for the decision to implement the concept of Lean Production

	$\bar{x}$	s
Improvement of flexibility (includes availability) in the utilization of equipment	4.6	0.5
Reduction in lead-time	4.6	0.5
Gains (or maintenance) in competitiveness	4.6	0.5
Inventory reduction	4.4	0.9
Reduction in planning errors (expected)	4.4	0.5
Intensification in the focus on the client/market	4.4	0.5
Reduction in the costs of manufacturing	4.0	1.2
Reduction of storage and production space	4.0	0.0
Scrap and rework reduction	4.0	1.4
Improvement of the efficiency of labor	4.0	0.0
Improvement in relations with customers	4.0	0.8
Redesign (optimization) of the layout of the factory	3.8	0.4
Improvement of profit margin	3.8	1.3
Quality improvement	3.6	1.1
Reduction of internal bureaucracy	3.6	0.9
Improvement of the quality of the acquired items and raw materials	3.2	0.8
Improvement in the reliability of the suppliers	3.0	0.8

For the companies using or planning to use the concepts of Lean Manufacturing the questionnaire asked them to classify the reasons for doing so, and evaluate their importance. There is a reasonable convergence in the reviewed literature regarding such motivations for the adoption of Lean Production. The work of Mahapatra and Mohanty (2007) in particular sets limits for the purposes of this inquiry. Table 3 displays the averages ($\bar{x}$) and standard deviations (s) obtained through the application of a five point scale where 1 indicates the minimum contribution ("did not contribute or contributed little") and 5 is the maximum contribution ("contributed decisively). The expectation of improvement in the flexibility in the utilization of productive equipment is among the three motivators classified as having the highest average, thus having the greatest contribution to the decision to adopt the concept. Recalling that we are dealing with companies with continuous processes and that the literature review describes their production equipment as relatively fixed, of shared use for several products and of high fixed capital, the expectation of flexibility gauged in the research seems to verify that proposal. At the other extreme in Table 3, the low score of the motivator "improvement in the reliability of the suppliers" is justified by the low incentive to promote large transformations in the relationship with the supply chain when dealing with a small number of suppliers which as a characteristic of the segment are almost always monopolists or oligopolists.

Continuing the analysis of the responses, 72.7% (eight companies) said that they either had not decided in favor of implementation or had less than 25% of an implementation plan concluded.. On the other hand, two companies placed themselves at between 50% and 70% of the total implementation and only one estimated being between 75% and 100%. At first glance, the sample provided a small percentage of companies that classified themselves as in the process of implementation or of effectively using lean production. Here there is a complex question regarding the measurement of how much and how, in fact, the company understands the concept of Lean Production as a philosophy with multiple tenets and tools and does not confuse the employment of one of the tools as having embraced the philosophy fully. Some authors have addressed this theme. Shah and Ward (2007) upon labeling it as a linguistic confusion, cite Plato who, in 360 BC, suggested that confusion arose because several terms may refer to the same object or idea, a single term may ambiguously refer to more than one object or idea, and the terms may be confused because they change over time. . The necessity of prudent interpretations that do not confuse prevails: for example, the adoption of participative improvement programs that may be labeled “Kaizen” as a given percent of the implementation of the Lean Concept.

In another question, asked because of the possible confusion cited in the previous paragraph, it was asked how the company perceived Lean Production. As such, five statements were offered, to which the respondents were asked to utilize the following scale: 1 – Very strongly, 2 – Strongly, 3 –Moderately, 4 – Lightly and 5 – not Perceived. The statement “as a fad” had an average of 4.2, denoting the perception that the concept is more than a simple utterance of *pop management*. About being a set of management techniques and tools principally of production, the mean was 2.7, suggesting that the concept still carries a label of being a factory floor concept. The literature review corroborates that perception even considering the evolution of the concept through the years. See, for example, Hines et al (2004). About being ‘a method for the improvement of productivity’ the average score was 1.9. None of these results were significantly altered when stratified by the replies “yes” or “no” to the question about having implemented, being in the process of implementing or having decided for the implementation of the concept. However, this differs from the results when the statement “concerns a concept partially approached by my company” is submitted. Here the respondents had a mean of 3.3. However, upon stratifying those that responded “yes” the grade changed to 4.0 versus 2.7 of those who said “no”. In the same sense, in the final assertion of this series, “is a concept with a holistic approach in the company” the mean was 3.3 in the same stratus went to 2.6 for those who said “yes” and 3.8 for those who said “no”. The suggestion here is that companies that have decided for the adoption of the concept developed a wider and unobstructed vision of the possible limitations to the full utilization of the concept. Regarding the typical techniques and tools of Lean Production there is a reasonable consensus among the authors. From the works of Mahapatra and Mohanty (2007), Shah and Ward (2007), Bhasin and Burcher (2006) and Godinho and Fernandes (2004), 16 tools and techniques of Lean Production were identified as common by the authors. For each one of them, a question was asked regarding the applicability and the efficiency in the company adopting the

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following scale: 4 – Applicable and extremely effective, 3 – Applicable and effective, 2 – Applicable, but not very effective, 1 – Not applicable. The respondent was oriented to not respond if he were not sufficiently familiar with the tool. In a subsequent question the status of the implementation of each one of the same techniques was requested. In this case, a scale of three points was adopted: not implemented, in the process of implementation and implemented. The results are compiled in Table 4.

The tools "*Takt-Time*", "*Poka-Yoke*" and "*Jidoka*" presented the highest percentages of blank replies and, in accordance with the form instructions, suggest lack of knowledge on the part of the respondents. Even so there is not an indication of correlation between the tools with a higher rate of not being filled out (and presumed not known) and their percentage of implementation. Naturally the lack of knowledge on the part of some responders does not impede the effective utilization by other companies of the sample being studied. In the same manner, there is an evident correlation, to a certain degree expected, between the better-scored tools with respect to the applicability and effectiveness and the respective percentage of implementation. However, it must be noted that the top scoring refers to those tools taken as universally applicable, independent of the manufacturing environment and this is the obvious case of the "Kaizen", "5S" and "Visual Management" tools.

Table 4 – Lean Tools

	Applicability and Effectiveness			Utilization		
	Average	Standard Deviation	Without Score	Not implemented	In implementation	Implemented
Kaizen: continuous improvement effort	4.0	0		9.1%	36.4%	54.5%
5S	3.7	0.5		18.2%	18.2%	63.6%
Visual Management	3.7	0.5	9.1%	27.3%	45.5%	27.3%

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Work standardization	3.7	0.5	9.1%	18.2%	63.6%	18.2%
TPM – Total Productive Maintenance	3.6	0.7		36.4%	45.5%	18.2%
Multi-functional worker / rotation of functions	3.6	0.5		18.2%	36.4%	45.5%
Rapid set-up	3.5	0.5		18.2%	63.6%	18.2%
Teamwork (Quality Circle, Small Group Activities and other forms of group work)	3.5	0.5		27.3%	36.4%	36.4%
Takt-time Production (synchronized production)	3.4	0.5	36.4%	63.6%	18.2%	18.2%
Poka Yoke	3.2	0.8	18.2%	63.6%	27.3%	9.1%
Continuous flow (one piece flow) / Lot size reduction	3.2	0.8		63.6%	18.2%	18.2%
Pull production system (kanban, containers or boundaries as production control)	3.2	1.2		27.3%	54.5%	18.2%
Mapping of the value flow	3.2	0.6		18.2%	63.6%	18.2%
Jidoka/"autonomation"	3.1	0.9	18.2%	60.0%	40.0%	
Just-in-time supply and receipt	2.7	1.4		63.6%	18.2%	18.2%
Manufacturing Cells	2.3	1.2	9.1%	63.6%	18.2%	18.2%

Another statement concerns the tools taken as structural in the concept of Lean Production, such as the reduction of lot size, the pull system of production or the mapping of the value flow being classified in the in the median portion (either by the mean or by the mode) in the classification obtained among the respondents. From the point of view of implementation, such tools are found predominantly in implementation or not implemented. The *Jidoka* tool, taken by Ohno (1988) as one of the pillars of the Toyota System of Production presented the highest percentages of "not implemented", a high rate of lack of knowledge and a lower than average evaluation of applicability and efficiency. A possible inference is that it is justly the difficulty of customization of these tools to the industrial environment that is the object of the study. As suggested previously, the possibility of a superficial and hasty interpretation of the tools could be assumed as possible, particularly regarding those that are better-known, in which it is incorrectly understood that such tools are the concept itself. Similarly, there may be an understanding that the concept is summarized by a list of applicable tools or is just another quality or productivity improvement program. This may arise from sponsorship of the vigorous and vaunted results of the automotive industry (the "industry of industries" as said by Peter Drucker, cited by Womack et al, 2007). In either of these hypotheses the

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intention of avoiding this metonymic confusion demands a greater depth through case by case evaluation through more in-depth studies than a survey.

A final question asked about the expected (or already obtained) benefits of the adoption of Lean Production. Seven potential gains were presented based on the literature and in particular in the work of Mahapatra and Mohanty (2007) in which the following scale was offered: 5 – Very High; 4 – High; 3 – Moderate; 2 – Low or 1 – not known. The result is displayed in Table 5 through the means ($\bar{x}$) and standard deviation (s).

Table 5 – Expected Benefits

	$\bar{x}$	s
Improvement of the service level	4.3	0.6
Improvement of client satisfaction e	4.2	0.8
Reduction in delivery time	4.1	0.8
Reduction of the lead-time	4.1	0.8
Reduction of costs	4.0	1.2
Increment of the flexibility of manufacturing	3.9	1.0
Reduction of the time for development of new products	3.1	1.4

The improvement of the level of service appears in the top, corroborating the perception of the respondents regarding the concept of how higher availability, incident reduction and nonconformity leverage better performance. The increment in the flexibility of manufacturing, even though in the next-to-last position, displays a score near “high” and does not fundamentally diverge from the result obtained upon asking the companies who responded “yes” to the question of having implemented, of being in the process of implementation or of having decided in favor of the implementation of the concept, recalling that here the entire sample was consulted. In last place, the time for development of new products is justified by the normative and standardized character of the products in the segment, principally conductors intended for distribution and transmission of electrical energy.

5. Final Considerations

Supported by the deliberate choice of a sample that fits the scenario of companies that manufacture conductors, which presumably would have a sound conceptual understanding of lean concepts) , the results obtained in this survey reveal an immature phase in the adoption of the “lean company” philosophy. From the data that was collected, collaborated by the participation of large companies with foreign capital that composed the sample, the segment does not seem to have mastered the concept, as it also does not make disseminated use of the more complex tools from the perspective of the customization to the continuous manufacturing environment. Finally, the adoption of the lean concept in the electric conductor industry still requires a more significant evolution both in the dissemination of ideas in a complete form as for the customization of the tools. This may explain the lack of scientific literature that discusses cases in the sector.

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