A Study About The Level of Lean Usage in Plastic Industry

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Abstract

Lean production strategy was created around the 1950's in Japan and has been developed and applied worldwide since then. In Brazil, this strategy arrived during the 90's and its application became a standard in successful industrial organizations. Therefore, it would be reasonable to suppose that nowadays lean production principles would be widely applied in Brazilian industrial companies. Thus, the aim of this research is to confirm this supposition in the context of the Brazilian plastic industry.
The study was approached through a survey research. A sample of eight plastic companies was considered and the instrument used was a questionnaire based on a bibliographic research developed by Brazilian and Portuguese researchers. Levels of compliance of each item was transformed in a numerical rating scale. Originally in English, descriptions of items were translated to Portuguese and adapted to Brazilian industrial language.
Results were analyzed one by one, and all together. Surprisingly, four companies have declared low knowledge and use of lean principles and tools. Three declared to have a good level of knowledge and application. One is in the middle level.
Differently from what was supposed initially, lean strategy is not so well known and used in the sample of plastic industries.

Keywords
Lean Production System, Plastic Industry, Survey Research, Questionnaire .

1. Introduction
Lean Production System (LPS) appeared for the western world during the 1970's and, initially had been understood as the opposite of Mass Production. The evolution of researches and the application of LPS have showed that, in fact, it is an evolution of that production strategy.
Lean Production is a concept created by Toyota during the 1950's in Japan. When this concept emerged in Japan, after WWII, the country was poor in raw material, production equipment and specialized workers. Without resources, the strategy was to avoid all kind of wastes in the production processes (WOMACK, 1992). According to Lean Production philosophy, wastes that must be avoided are motion, inventory, waiting, defects, overproduction, transportation, and overprocessing. Moreover, LPS is based on four basic rules: i) all activity must be specified concerning to content, time and results; ii) relationship between customer and supplier (internal and external) must be direct; iii) flow of work and process must be simple and direct; iv) every improvement must be done according to scientific methodology, strong orientation and in the lowest level of the organization (MARTINS and LAUGENI, 2005). During the next two decades, after the emergence of LPS, this concept has been tested, enhanced and consolidated as a production system widely applied in Japanese industry.
At the same time in the West, mostly in USA, the predominant production model was the Mature Mass Production, an evolution of the Pure Mass Production. The Pure Mass Production model was based on Taylor's principles, added with successful practices of Henry Ford and it was "lean", since this definition did not exist at that time (1920's). During the next fifty years this system adapted to evolve according to the customer's requirements, like more personalized and sophisticated products. This evolution resulted in Mature Mass Production that accepts many inefficiencies in order to attend a market avid for products. This kind of market allows to charge high prices for products with not so good quality. The abundance of resources in the USA after WWII made this strategy, inacceptable according to today's mindset, very logical, profitable and natural standard of production systems.
The second petrol crisis, in 1973, transformed the economy and increased dramatically the competitiveness among companies worldwide. In this environment, Japanese companies surprised American and European competitors with high quality products and low prices. The ability to make such superior products is a consequence of the LPS (WOMACK, ROSS and JONES, 1992).

American and European companies noticed that surviving depended on the adoption of the LPS, what meant to change completely the mindset, eliminate wastes and use completely the human capacity of workers, much more than the physical force like in the Mass Production system.
During the next two decades LPS became the standard production system (both in manufacturing and services) in USA and Europe (WOMACK and JONES, 1997).
In Brazil, due to a long period of closed economy, concepts of the LPS arrived in the end of the 1980's and their understanding, alongside with its widespread, delayed up to the end of the century. During this period, some few companies adopted LPS and some of them became a worldwide benchmark in their economic segment, but these few companies were a very small part of the Brazilian economy (AMATO NETO and SILVA, 2000). So, the research question that this paper intends to answer is if, in 2019, companies of the plastic industry, a very competitive segment, know and use, wholly or partially, the LPS. The initial hypothesis is that LPS (philosophy, principles and tools) would be known by plastic companies and used in different levels by them.
This study has been developed in São Paulo State, more specifically in the Sorocaba city, that is a region with high number of industries and, some of them, are suppliers of Toyota, which has a factory in the same city.
The paper is organised as follows. In section 2, the methodology used will be presented. Section 3 presents the empirical study and its main results. Moreover, finally, in section 4, the main conclusions are drawn, and research limitations and future research topics are presented.

2. Methods

2.1 Research Methodology

A research methodology based on a survey method was selected since it allows collecting the perceptions of plastic industry managers about the adoption and application of lean manufacturing system principles, concepts and tools. This research fall within an exploratory survey research type. As explained by Karlsson (2016) exploratory survey research takes place during the early stages of a research on a phenomenon when the objective is to gain preliminary insight into a topic, and provides the basis for more in-depth survey research. Data were collected through a structured questionnaire instrument that was designed based on previous literature. So, initially, a literature review was carried out on the topic of Lean assessment. Various publisher´s electronic databases, namely Science Direct, Scopus and Web of Science were used to find the relevant articles. International standards (SAE J4000 and SAE J4001) (SOCIETY of AUTOMOTIVE ENGINEERS, 1999) and a study with analyses of these standards have been used to elaborate the questionnaire (SILVA, 2002), as well. Moreover, the rule for search engine was based on the variables identified in the research scope. So, the following set of keywords-based searches were applied to collect articles: "lean implementation assessment" + "tool(s)"; "lean(ness) assessment" + "framework"; "measuring lean(ness) implementation" + "model"; "lean implementation maturity" and "lean capability maturity". The team carried out the examination and selection of the articles, to define a set of assessment elements to evaluate the LPS and its level of implementation in an industrial context. Based on this research, Table 1 was constructed with the elements mentioned in nineteen works from the literature.

Table 1. Lean assessment elements reported in literature

Authors / Elements	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	%
Management / Commitment							X				X	X	X			X	X	X	X	42.1
People		X			X			X		X				X		X	X	X	X	47.3
Information		X						X				X						X	X	26.3
Suppliers/Enterprise/Customer		X	X		X			X			X		X		X	X	X	X	X	57.9
Product		X						X	X	X				X	X	X			X	42.1
Process/Flow		X		X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	84.2
Elimination of waste	X		X	X	X			X		X	X					X				42.1
Continuous improvement	X	X	X	X	X	X				X		X	X			X				52.6
Zero Defects	X					X		X	X					X	X	X				36.8
Just In Time	X		X		X					X	X		X	X	X	X				47.4
Pull insead of push	X	X		X	X	X	X	X	X	X	X	X		X	X	X	X			78.9
Multifunctional teams	X		X	X	X	X	X	X	X	X		X				X				57.9
Decentralized responsibilities	X							X				X								15.8
Integrated functions	X															X				10.5
Information systems	X		X	X			X					X								26.3
Preventive Maintenance					X	X						X		X		X	X			31.6
Standardized work							X			X	X	X		X	X	X	X			42.1

Legend: (1) Karlsson, C and Åhlström, P. (1996); (2) Abreu, A., Calado, J.and Vargas, J. (2015); (3) Sánchez, A, M.and Pérez M. P., (2001); (4) Vienazindiene, M. and Čiarniene, R.. (2013). (5) Shah, R. and Ward, P. (2007); (6) Stone, K. (2012); (7) Bhamu, J.; Sangwan, K. S. (2014); (8) Doolen T. and Hacker, M. (2005); (9) Netland, T, Schloetzer, J.and Ferdows, K. (2015); (10) Moyano-Fuentes J., and Sacristán-Díaz, M. (2012); (11) Jasti, N. and Kodali, R. (2015); (12) Marodin, G.and Saurin, T. Tortorella, G.and Denicol, J. (2015); (13) Bortolotti, T, Boscari, S. and Danese, P. (2015); (14) Marodin, G. and Saurin, T. (2013); (15) Stentoft, A. and Vagn, F. (2013); (16) Netland, T. and Ferdows, K. (2014); (17) Goodson, E.R. (2002); (18) Pearce, A., Pons, D. and Neiztert, T; (19) Society of Automotive Engineers, 1999.

Then, the most relevant elements were selected, as consequence of the aggregation of the elements presented in Table 1, considering the highest percentage of each element mentioned by the authors (last column of Table 1) and a rearrangement of elements. So, the questionnaire included the following assessment elements: 1) Management/Commitment; 2) People; 3) Information; 4) Suppliers and customers; 5) Product; 6) Process; and 7) Continuous improvement. A set of items was associated to each element of the questionnaire to evaluate it. The questions were chosen based on the literature review and revised and discussed iteratively among the research team. Also, the team members agreed on aims, approach and interpretations of the data regarding the questionnaire creation and application. The items use the 5-point or 6-point likert scale. The description of each item was created in Portuguese language and afterwards adapted to Brazilian industrial language.
Regarding the sampling process, the team started by agreeing on the respondent profile type and identifying a set of companies belonging to the plastic sector in Sorocaba region. Also, before sending the questionnaire, researchers have talked with the respondents by phone call, explaining the target of the research and how to answer the questionnaire.
The findings resulted from the analysis and synthesis of the data collected until October 2019.

2.2 Empirical Study

The initial approach was done with a group of twenty companies. Before sending the questionnaire, researchers have talked with potential respondent, explaining the target of the research and how to answer the questionnaire. In spite of these cares, just eight companies accepted to take part of the research. These companies have been numbered randomly from 1 to 8.
Just one company of this group has more than 250 workers (company 6). One of them has less than 10 workers (company 1). Two companies have more than 50 and less than 250 (companies 3 and 5). The other four companies have between 10 and 49 workers (companies 2, 4, 7 and 8).
Three companies describe their organizational structure as “simple”, what means that there is a manager (normally the owner) that takes care of all business (companies 2, 4 and 7). The rest of the companies follow the “functional” structure that means each company is shared in departments with traditional functions and responsibilities.
All companies declared to be second or first level supplier, that means that they deliver products to other companies. Probably due to this relationship with industrial clients, six companies have a quality system certification, like ISO9001-2015 (ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS, 2015). Only companies 1 and 7 do not have it.
None company has a specific department dedicated to continuous improvement. Regarding the organizational maturity level relative to the lean production system, four companies declared to have no experience in LPS (companies 1, 4, 6 and 8), and one (company 5) declared to have one year of experience in LPS. All of these five companies, obviously, assumed a low level of maturity in LPS. Three other companies declared to have more than fifteen years of experience and that they have an intermediate level of maturity on it. Table 2 shows the maturity level of each company.

Table 2: Maturity level of each company.

Company	LPS maturity Level	Group
1	low	3rd
2	intermediate	2nd
3	intermediate	1st
4	low	3rd
5	low	1st
6	low	3rd
7	low	3rd
8	low	3rd

In order to analyze the results, the companies have been organized in three groups according to their answers to the technical questions about understanding, use and results of tools and methodologies of LPS and to the commitment of administration with LPS. Table 3 shows basic information of each group.

Table 3: Basic information of each group.

Group	Companies	Commitment of Administration	Training	Level of Use of Tools, Methodo-logy and Principles	Process Documents Available and Used	Partnerships
1st	3 and 5	high	always	medium	always	always
2nd	2	medium	always	medium	always	always
3rd	1, 4, 6, 7, 8	low	sometimes	low	sometimes	sometimes

The first group, formed by companies 3 and 5 have a high commitment of administration with LPS, meaning that top management has an active role in the practical implementation of LPS in the organization, with direct and regular involvement with the workforce. Workers are trained and use tools and principles of LPS in a medium level. Process documents are available and used in daily operations. The partnership with suppliers and customers happens in an intermediate level, but efforts to reduce product time development are intense. These companies know and use (in different levels) many tools and methodologies of LPS to improve products and processes like 5S, kanban, 6 Sigma, DFA (Design for Assembling), DFM (Design for Manufacturing) and QFD (Quality Function Deployment), and in a general way, attribute good results to this use. Company 3 knows FMEA (Failure Mode and Effect Analysis) but does not use it. Company 5 uses FMEA with very good results. Only company 5 knows TRIZ (Theory of Inventive Problem Solving) and uses it, showing good results, what is not usual because this tool is very sophisticated, and few companies apply it. When the key point is methodologies, principles and tools for processes management and improvement, like 5S, andon, bottleneck analysis, gemba walk, standardized work, just in time, root cause analysis, visual management, value stream mapping, PDCA (Plan, Do, Check, Act) and KPIs (Key Performance Indicators) are known and used. Both companies do not know heijunka. Company 3 does not know poka yoke, that is supposed to be a popular methodology to avoid mistakes and accidents. In a similar way, company 5 does not know TPM, a popular methodology to manage maintenance. The same happens with VSM (Value Stream Mapping). In a similar way, company 5 does not know TPM (Total Productive Maintenance), a popular methodology to manage maintenance.

In both companies the production depends on the customer's request and in most of the time they respect the takt time and the one-piece flow. In companies 3 and 5 there is a strong commitment to continuous improvement process, but results are not completely shared with workers at all level. In few words, these two companies certainly are not the best in class concerning LPS, but they apply many tools and methodologies and they report good results with them.
An interesting point is that company 3, when asked to rate its maturity level of LPS implementation assigned itself a medium level of maturity (what looks like appropriate), but company 5 assigneded itself a low level of maturity, what can be interpreted as being very severe with itself or as a wish to implement more LPS tools and methodologies in order to get better results.

The second group, formed only by company 2, has a medium level of commitment of administration with LPS. Workers are trained and use tools, methodologies and principles of LPS in a medium level. Process documents are available and used in daily operations. The partnership with suppliers and customers happens frequently, and efforts to reduce product development time are intense. This company knows some tools and methodologies of LPS to products and processes improvement but do not use or rarely use them. These tools and methodologies are 6 Sigma, QFD, TRIZ, bottleneck analysis, gemba walk and TPM. Tools widely used are 5S, FMEA, andon, heijunka, poka yoke, standardized work, just in time, root cause analysis, Kanban, visual management, value stream mapping , PDCA and KPIs. VSM is rarely used.
In company 2, the production depends on the customer's request and it usually respects the takt time and the one-piece flow. In company 2 there is not a strong commitment to continuous improvement process, but results are widely shared with all workers. In a few words, this company does not have a good level of implementation of LPS. The company

2 assigns itself as medium level of maturity, what does not look like appropriate because low commitment with continuous improvement is contradictory with basis of LPS.

The last group, formed by companies called number 1, 4, 6, 7, and 8, assign themselves a low level of maturity, and it looks like appropriate. These companies indicated a low level of knowledge and use of tools and methodologies of LPS. Company 1 (in a medium level) and company 7 (in a low level) indicate that LPS is a part of administration concerns and plans. Same evaluation is indicated about workers participation in LPS. Nevertheless, all other answers show that this evaluation probably reflects wishes and not a technical point of view. Companies 4, 6 and 8 indicated the lowest level of punctuation (zero) in most of the questions about these topics, concerning workers and administration. It is important to show that some specific tools are applied in an isolated way, not as a part of a wide action to implement LPS. For instance, a company pointed excellent results with the use of FMEA and 6 Sigma and does not know or use all other tools and methodologies. Similar thing happens with company 6, with SMED. About production organization, the results are different among these companies. While companies 1, 2 and 8 say that takt time is always or frequently respected, other companies say that it happens seldom or never. Just company 7 says that one-piece flow is not respected. Production based on the customer's requests happens always in companies 2, 4 and 8, sometimes in companies 1 and 6 and rarely in the company 7. It was expected that companies 1 and 7, which do not have any quality certification, do not have a well implemented continuous improvement process. What is surprising is that companies with strong certifications, like ISO9001-2015 (ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS, 2015) and IATF16949-2016 (INTERNATIONAL AUTOMOTIVE TASK FORCE, 2016), do not have an effective continuous improvement process. The only exception is the company 4. Results are shared with workers at all levels, but always in a low scale. Therefore, companies of this group have a poor application of LPS and the use of few tools and methodologies that are applied is probably caused by an external factor, like customers or ISO9001-2015 (ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS, 2015) audits. VSM is not used by these companies.
Table 4 shows the use of tools by each company.

Table 4: Level of adoption of some LPS tools and methodologies by each company.

	COMPANY (Group)							
Tool	1(3rd)	2(2nd)	3(1st)	4(3rd)	5(1st)	6(3rd)	7(3rd)	8(3rd)
QFD	N	R	C	D	C	C	C	N
FMEA	N	C	D	C	C	C	D	C
6SIGMA	N	R	C	D	D	R	D	C
5S	N	C	C	D	C	D	R	D
TPM	N	C	C	N	C	D	D	D
VSM	N	R	N	N	N	D	D	D
KANBAN	N	C	C	D	C	C	D	D
PDCA	N	C	C	N	C	N	C	C
POKA YOKE	N	C	N	D	C	N	N	R

Legend: C: knows and is used ; D: knows, but does not use ; N: does not know ; R: knows but rarely is used.

3. Conclusion

This paper aims to study the deployment of Lean Production System principles, methodologies and tools in companies from the plastic sector in the region of Sorocaba, Brazil. To attend this objective, a questionnaire was applied to a set of eight professionals.
Regarding the adoption of LPS, the questionnaire has proved to be useful in collecting detailed information about LPS implementation and use in companies of different sizes and organization.
Despite the questionnaire being a bit long, its questions allowed to detect some contradictions in the answers that could expose the difference between intentions and actions of managers and companies.
The analysis of the results demonstrated that the initial hypothesis (LPS would be known by plastic companies and used in different levels by them) is not true. This finding is very surprising because LPS principles, tools and methodologies are widely disclosed in Brazil since 1990's. This disclosing happened not only in technical and academic environment, but in popular media as well. Of course, the discussion in popular media is not deep enough to modify a company but should be enough to call out the attention of managers and owners of companies that something new was happening.

Here, is possible to detect an interesting contradiction: according to LPS philosophy, it is difficult to an organization survive without eliminating wastes, but, in the real world, some companies are surviving for more than 30 years without using LPS principles. Certainly, these companies would have better results if they used LPS but, anyway, they survive. To understand why and how these companies survive could be the subject of another research.
Among companies that took part in the research, some of them indicated high use of LPS principles, tools and methodologies, but they rated their own level of knowledge in LPS as intermediate. It shows that these companies know that there is yet too much to do to achieve a reasonable level of LPS.
Finally, this scenario drives the analysis to one more fundamental question. LPS implementation needs some investments in physical structure, managerial practices, human resources and training. This implementation can be done easier with the use of information technology, but it is not obligatory. The question is, if LPS that is based on a relatively low investment, is still poorly used by some small and medium sized companies in spite of too many information available, what should we expect about new technologies that ask high investments in physical equipment, software, hardware, people training and so on? Will this kind of company disappear or will it find a way to survive, like it has been doing without the LPS?
Besides the contribution of this research, some limitations are identified, to be addressed as future research, such as a larger sample of professionals from the plastic sector should be used to make the conclusions more robust; and also, to generalize the findings of this research it would also be useful to research other sectors since this research is focused only on the plastic industry.

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Biography

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