Tool Development for Support Lean Manufacturing Implementation in Intermittent Production Environment

T. Ferreira, A.A. Baptista, S. Azevedo, F. Charrua-Santos

Abstract—**The environment faced by organizations request the adoption of more efficient management models and practices in order to increase their competitiveness. In this context, Lean philosophy, in particular Lean Manufacturing has proven to be an extremely powerful management paradigm.**

However, the Lean philosophy when is applied incorrectly may turn out to be a failure for the organizations. In this sense there are several factors that can hamper the correct development of Lean Manufacturing within organizations such as i) Lack of commitment by top management; ii) Lack of qualified and graduates employees without know how on this paradigm; iii) Lack of guidance on application of tools and methodology of Lean Manufacturing.

This research shows that over the past few years, tools have been developed within Lean Manufacturing relating it to different types of industrial environments. However, guidelines for implementing this paradigm "step-by-step" is missing.

Thus, this master research suggests a framework for implementing the Lean Manufacturing in industrial environments, in particular, Job-shop.

Index Terms— **Lean Manufacturing, Lean Philosophy, Framework, Job Shop, Case Study.**

I. Introduction

Organizations with complex production processes, such as intermittent or job shop process, report an increased difficulty in the implementation of Lean Manufacturing (LM). One barrier observed in different job shop industries is the lack of a guiding tool with the objective of implementing the lean manufacturing in this environment. One of the difficulties faced was the difficulty to identify where to apply a policy of continuous improvement and the other tools of the LM. Obviously in this environment, as in the others, a strategy is needed to implement the lean philosophy as well as a training plan to promote the involvement of collaborators. As a result, this sector shows the need for a new methodology development to guide the implementation of the LM.

T. Ferreira is a Msc in Engineer and Industrial Manager at UBI, Lean General Manager.at OGMA, Lisbon, PT; (tiagoferreira19713@gmail.com)

A.A. Baptista is a Phd Student of C-MAST Center for Mechanical and Aerospace Sciences and Technologies, UBI, Portugal (amilcarb@ubi.pt)

S. Azevedo is Professor at University of Beira Interior, Department of Management and Economics, Covilhã, Portugal (sazevedo@ubi.pt)

F. Charrua-Santos is the Corresponding Author, Professor at University of Beira Interior, Electromechanical Department and member of C-MAST; Adress: Calçada Fonte do Lameiro, Ed. I das Eng, Electromechanical Dept., 6200-001 Covilhã (Tel: 275329754, e-mail: bigares@ubi.pt).

Organizations are encouraged to produce with higher added value. However these job shop processes are characterized by a big multiplicity of demanded products and companies are often faced with the incapability to meet the increased requirements, because they don't have the right organization to answer this need. To get over these difficulties it is necessary rethinking and restructuring processes, eliminate waste and activities that don't add value to products or services. Companies aims meet the needs of this markets with a high internal stability [1]. Also the companies are confronted with the need to high flexibility to respond to an increasing fragmented demand, and at the same time improve the productivity through reduction of waste.

One example is the automotive industry, which is considered a reference as it is conciliate high production levels, quality and flexibility through innovative designs organization models. The measures taken by this industry, particularly by component suppliers have come to meet the cost reduction maintaining the high quality. Some of these measures have gone through the analysis product by reducing costs but simultaneously improving performance in terms of quality. Currently the quality of the components has as a reference 20-30 low quality Parts Per Million, (PPM), while a decade ago the goal was from 1000 to 2000 PPM [2]. Also in the automotive industry the reduce of lot size resulting from the variation in demand and increased customization of products was felt significantly. To reply to this reality innovative management models were adopted, such as just-in-time (JIT) which has the intention of making the production more flexible and increase quality levels, without rupture because in this industry there are significant economic penalties for suppliers delays [2].

The globalization, in addition to changes in market behavior, also conditioned other significant factor the price. While a few decades ago the price was imposed by the producer it is now imposed by the market. As a result, in order to maintain margins that allow it to survive, companies force themselves to reduce the cost of production, to create added value as a result of improvement of quality and responsibility to customers. In resume, the global market has forced companies to produce more quality diversifying its offer, which led to smaller production batches, in the limit of piece by piece production, with the delivery times shorter and shorter. In this context, the aim of this chapter is an exploratory way, review the application of Lean philosophy in intermittent production system or Job shop (JS).

ISBN: 978-988-14047-0-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

II. Classification of Production

The classification of production isn't easy as a result of the big number of different processes. However some classifications have prevailed: i) by type of production; ii) by product characteristics; iii) by production environment; iv) by characteristics of the production flow.

In This work was adopted the classification by characteristics of the production flow.

It is now usually accepted that the discrete manufacturing systems can be classified according to the characteristics of production flows of the components in the following categories [3][4][5]: (I) Intermittent (job shop), (ii) lots (batch), (iii) line, this case can be divided into two sub categories: mass and continuous production (Flow shop, shop process).

Production of small batches of a variety of products, especially when these have a different sequence of processes have the Anglo-Saxon designation of Job Shop (JS). In this environment, the equipment is arranged, habitually in work centers according to their characteristics.

The job shop environment, JS, is characterized by the production of different orders in different flows. Each work order consists in a set of tasks or jobs that are processed only one time in each machine. There are many constraints in the operations and machinery level, namely: i) the sequence which operations are processed can vary; ii) operations after begin can't be interrupted and each machine can operate only one task at a time; iii) each task is processed in only one machine at a time.

The batch process, Batch Shop, differ from job shop process essentially by the way it processes the sequence of operations. In the Batch Shop the sequence is the same for all products.

Assembly Line, differs from Batch Shop essentially by the size of the batch, bigger in this case.

As mentioned above, different factors have been forcing the diversification and fragmentation of production which accentuates the tendency of companies to develop more complex processes as the job shop and simultaneous more flexibles.

III. Lean Manufacturing

The Production System developed by Toyota within the automobile production in Japan, Toyota Production System (TPS) is, among the known models, one of the most efficient in the elimination of waste and production flexibility [6]. This developed working philosophy is today a case study as an organizational model. Their success around the world, results in a methodology that would be called "lean production" or the Lean Manufacturing [7].

A. Lean Manufacturing in Production Processes

Some studies have been developed in order to optimize the application of LM, in particular by establishing guiding tools in the application of this paradigm in different industrial environments. These tools are a guidance to solve the deficiency skills sometimes responsible from the failures in the application of LM. Abdulmalek et al. (2006) in order to orientate the implementation of LM, suggests a classification that sets the processes according to their suitability for the implementation of the LM [8]. However this classification identifies few processes. Subsequently, Rathi and Farris (2009), have continued the classification developed by Abdulmalek, building a more complete classification with more variables by adding features of interest, resulting in a clearer and complete classification model, see Table I [9]. The application of LM varies with the industrial environment. This classification simplifies the processes differentiation. The processes are characterized by different variables, as can be seen in Table I. As result are identified different approaches to the application of LM. However, this analysis needs more intensive studies in some types of production like the Job shop environment. Anand and Kodali (2010) presented a study about the LM implementation in different types of industry. We can see that the LM has been implemented in many different industrial environments in the last years[10]. The literature also shows that the number of studies about LM implementation is bigger in the automotive sector [8] [11] - [15]. According to the literature, the auto industry continues to be a model in the application of LM [16].

The authors report that none of the studies provides a "step by step" or a guidance tool to the application of LM methodology. The approach to implement the LM is different from an industrial unit to another, from one production system to another, so it is important to have guiding tools early in the process of implementation and some indicators about the major or minor appetence to implement .Though, there are some studies that relate the Lean tools with different waste [10].

IV. Proposal to a Support Tool in Job Shop Environment

Considering the above mentioned, it is pertinent the development of a methodology for the application of LM in intermittent environments that go beyond the results shown.

It seems clear that it is necessary to develop a methodology to the application of LM in intermittent environments, particularly in the initial phase of its implementation. The Lean philosophy includes tools aimed to the improvement and waste elimination such as the Value Stream Mapping (VSM). The VSM is a powerful diagnostic tool, but in more complex production scenarios the difficulties justifying a more detailed analysis.

Of the reasons for the failure and the difficulty in applying the LM, one can highlight three: i) the lack of top management commitment. The administration needs to understand the philosophy and commit to providing all the necessary means for its implementation. Top management must commit itself in changes in internal paradigms, working to become Lean and live with these principles; ii) Lack of qualified employees; iii) Lack of guidance on the application of LM.

The tool resulting from this work aims to improve the third point, the lack of guidance on the application of LM,

ISBN: 978-988-14047-0-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

especially in industries with intermittent production processes. In fig.1 we can observe the five phases of the proposed tool.

TABLE I

	Mass production	Batch Production	Job Shop Production
Demand	Very stable	Stable	Low stable
Demande volume (per product)	High	Medium low	Very low
Type of production	Standard to Stock	Standard By lots	Personalized, for demand
Raw material variety	Low	Moderate to high	High
Finish goods variety	Low	Moderate	High
Equipment's	Specialized / Dedicated	Dedicated	Flexible
Layout	Layout by Product	Layout Mix	Layout by Process
Materials Handling	Fix Flow	Mix Flow	Variable flow
Materials flow	Continuous	Continuous to Intermittent	Intermittent
Process flexibility	Low	Medium	High
Continuous to Discret	Latter	Medium to Latter	Early
Example	Sugar; Cotton; Rice;	Steel; Paints; Bakeries;	Metalworking ;

Adapted from (Rathi and Farris, 2009)

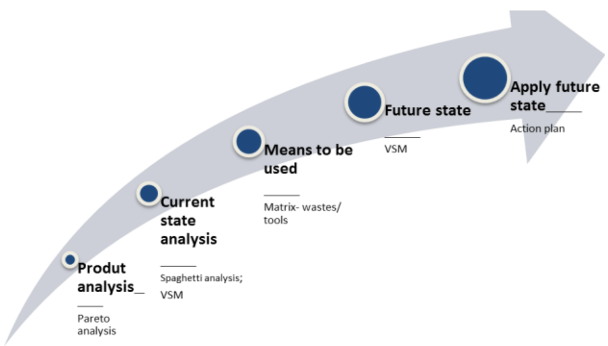

Fig. 1. Developed Tool Scheme

A. Step 1- Produt Analysis

In intermittent environments is more difficult to identify where to begin the implementation of Lean practices, the existence of many products and complex flows make it difficult to focus, so it is inevitable that make a careful analysis. This analysis aims to identify the most significant products, most representatives in sales volume and the volume of the business.

Organizations that produce a large number of products can't assign the same importance to all of them, because the costs associated with this control would be high. In this case it is customary to utilize the Paretto analysis to identify the most significant products. Paretto analysis can also be used to identify the products and flows most significant in applying the LM.

This tool has been used in numerous industries, and is one of the seven basic tools of quality [17]. The Pareto analysis follows the rule of 80:20, where 20% of the articles typically represent 80% of total sales [18]. Using the Pareto analysis in the current study should be made as follows: i) quantify all products manufactured and record them in a table; ii) quantify the products in sales volume; presenting the percentage of each product in relation to the total; prepare the cumulative percentage. The objective of this analysis is to identify the most representative product and analyze it in a perspective of LM philosophy. The application of LM for all production turns impossible its implementation. The Pareto analysis in this case is the beginning of the LM implementation. The Paretto analysis ranks the products. The choice must be based on the best-selling. This decision will take into account the company's strategy, for example, the product life cycle. The application of the LM to the product with more sales may have very positive results for the company, since it identifies and order the changes to make.

The selection of a product or family of products for implementing the Lean philosophy in intermittent environment not against the principle of LM based on continuous improvement. What has been examining throughout this work is the methodology to be followed to start the implementation of LM in intermittent production environment.

After the product analysis phase using the Pareto analysis is initiated the second phase.

B. Step 2- Current State Analysis

Identified the product, will be studying the value chain of this product. The aim is to quantify the activities without added value, waste.

The first step is to study the flow of materials in a visual way, to understand its complexity. The use of a spaghetti diagram is a possible method to visualize these movements fig 2. The preparation of a spaghetti diagram is made in a simple and intuitive way: the flow and the direction of the raw material is represented superimposed on plant equipment implementation [19].

The spaghetti diagram alone is not sufficient to proceed with analyzing the actual added value.

The spaghetti diagram represents only the materials flow throughout the process. To continue is needed analysis other important data for the characterization and quantification of the actual value added using other tools.

Lean presents tool for this purpose, the value stream mapping VSM, fig 3. The VSM is a process of direct observation of the information and material flows, by drawing them.

ISBN: 978-988-14047-0-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

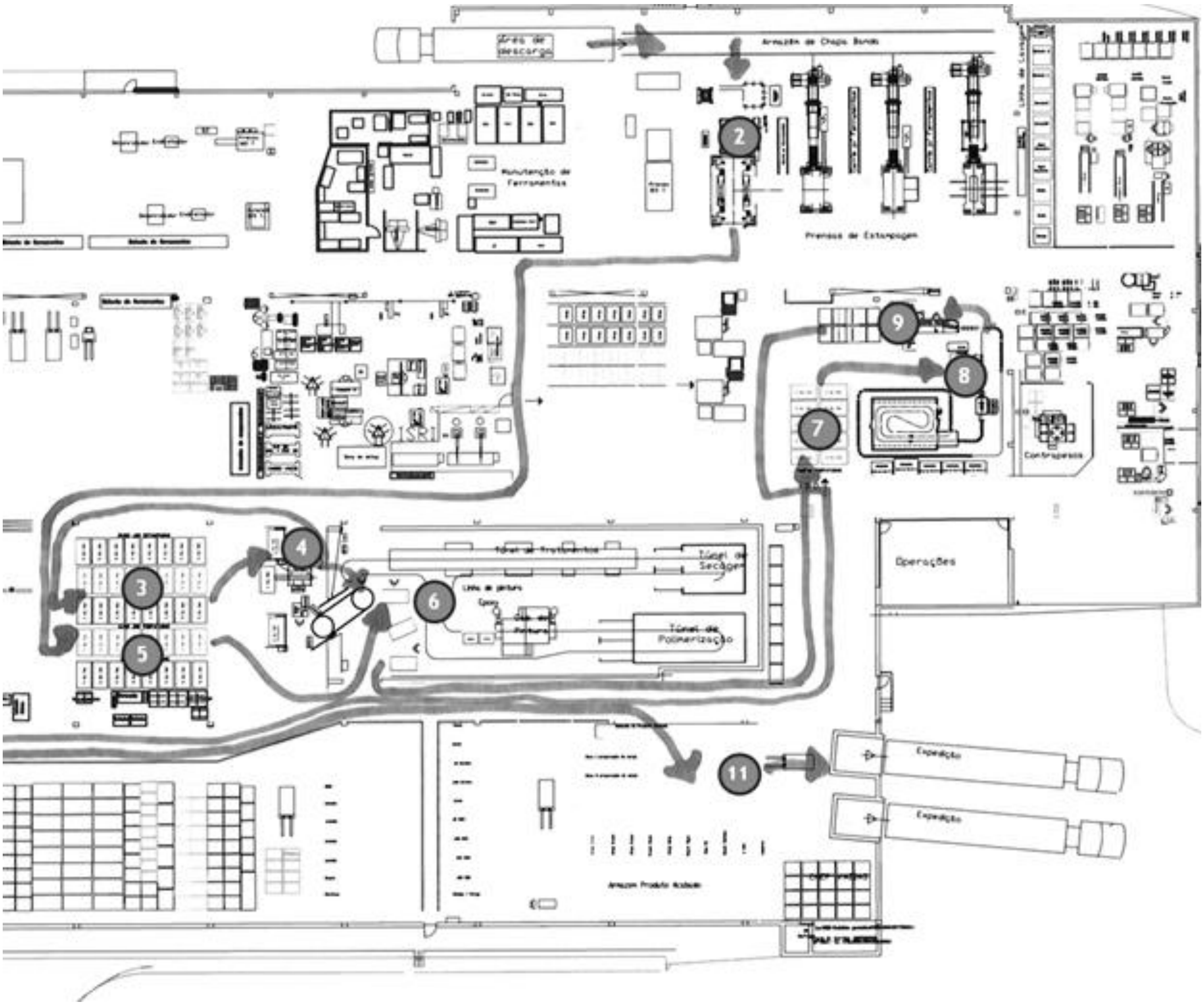

Fig. 2. Spaghetti Diagram

This tool helps the value chain visualization, highlighting the inefficiency of processes, and guiding to improve them. The VSM helps to visualize more than one process, it allows the visualization of the entire flow, allows also to relate the flow of information with the flow of materials associated [20]. The VSM is an essential part of the methodology presented by its characteristics at diagnosis, being an indispensable tool for the implementation of Lean [7].

This tool allows two views, the first, the current state, and the second of the future state, a situation for which you want to walk. At this stage, with the development of the current VSM, it's possible identify waste and its location. In step III will analyze the tools to use to eliminate waste found, aiming an optimized future state.

C. Step 3- Tools to be Used

With the current VSM prepared and analyzed, it is necessary to find solutions to eliminate or reduce the different identified waste. As discussed throughout this paper, the LM has many tools that can be useful. Rathi and Farris (2009) have a matrix that relates the waste found in Job Order production system Lean tools.

The Table II aims to provide a support base the decision on the selection of tools to be applied.

This matrix cannot be seen in an inflexible way, because there are factors that vary from organization to organization.

To designate the degree of relationship is used a range of 3 values as follows: 1 = some relationship; 2 = moderate relationship; 3 = high relationship;.

TABLE II

	5's	SMED	*Kanban*	*Heijunka*	TPM	SW	*Poka Yoke*	Celular work
Stocks		1	3	3				2
Movements	2					2		3
Transport	1							3
Quality defets			1		2	2	3	
overprocessing						2	3	
overproduction		1	3	3				
Setup time	2	3			1	2		

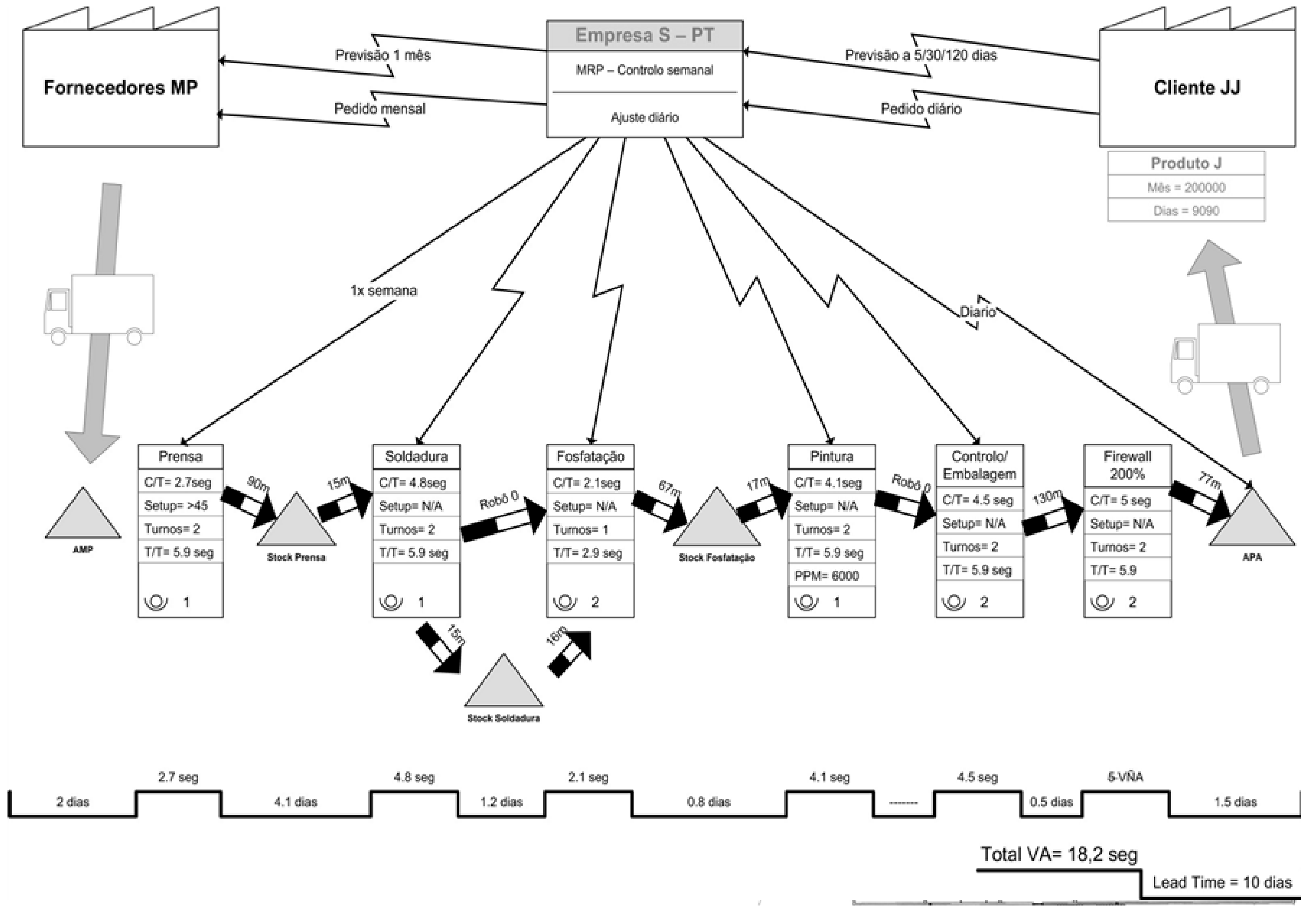

Fig. 3. Value Stream Map Example

D. Step 4- Future State

The future state aims to eliminate all sources of waste, linking all processes to the customer through a continuous and pulled flow. The aim is to produce only what is needed and when it is needed, eliminating all intermediate activities that not add value to the product to the customer's point of view.

For the preparation of the future state map has to take into account the tack time (TT), which processes can be integrated creating a continuous flow, which Pacemaker process used to pull production and set the pace, that supermarkets use, which processes need improvement [20]. In resume, the VSM future should show graphically how will the process be after the application of the tools described in the previous step.

E. Step 5- Apply Future State

The future status is the result of effective implementation of the previous steps. To the future state becomes real it's necessary put in practice the lean tools. This implementation must observe a detailed action plan. The fulfillment of this plan will depend on the success of the application.

V. Conclusion

The adoption of Lean philosophy as a management model for organizations requires a strong synergy of methodologies and tools with the culture in which the organization operates. It also has a strong commitment from management, clarifying business objectives of the application of lean. If there is no commitment of management potential gains from the implementation of this paradigm are lost or don't even truly be started. The focus of the work was directed to developing a tool with the purpose of optimizing the application of the LM in intermittent production environments.

The developed solution passed through the creation of a tool that gathers and organizes the tools already known within the LM as: VSM, spaghetti diagram and Pareto analysis. This collection of tools was made with the aim of defining what to do in each step of this process. The developed tool proposes a methodology, following a sequence of steps. These steps culminate in the implementation of the future state. This methodology aims to help implement the lean philosophy in intermittent environments.

This work opens the way to new research. It would be interesting to develop a tool for application in different industrial environments.

Acknowledgment

The authors wish to thank University of Beira Interior and C-MAST - Center for Mechanical and Aerospace Science and Technologies, for giving us all support that was needed.

REFERENCES

[1] Van Hoek, R., "The rediscovery of postponement a literature review and directions for research", *Journal of Operations Management* vol 19, pp 161-184, 2001.

[2] Barnes, J., Morris, M."Staying alive in the global automotive industry: what can developing economies learn from South Africa about linking into global automotive value chains?" *The European Journal of Development Research* Vol 20, pp 31-55, 2008.

[3] Chase, R.B., Aquilano, N.J., Jacobs, F.R., "*Operations management for competitive advantage*", McGraw-Hill/Irwin, 2006.

[4] Reid, R.D., Sanders, R.N.," *Operations Management*". John Wiley and Sons 4, 2010.

[5] Abduelmula, A., MacIsaac, R., ElMekkawy, T.Y.," *Lean manufacturing implementation to a robotic-press line",* AG Simpson Automotive Systems, 2005, pp. 19–22.

[6] Russell, R.S., Taylor, B.W."*Operations management: creating value along the supply chain*". John Wiley & Sons, 2011.

[7] Chen, L., Meng, B.,"The Application of Value Stream Mapping Based Lean Production System", *International Journal of Business and Management* vol 5, pp203, 2010.

[8] Abdulmalek, F.A., Rajgopal, J., Needy, K.,"A classification scheme for the process industry to guide the implementation of lean", *Engineering Management Journal* vol 18, pp 15, 2006

[9] Rathi, N., Farris, J.,"*A Framework for the Implementation of Lean Techniques in Process Industries*", Texas Tech University, 2009.

[10] Anand, G., Kodali, R., "Development of a framework for implementation of lean manufacturing systems", *International Journal of Management Practice* vol 4, pp 95-116, 2006

[11] Domingo, R., Alvarez, R., Peña, M.M., Calvo, R., "Materials flow improvement in a lean assembly line: a case study", *Assembly Automation* vol27, pp141-147, 2009.

[12] Gunasekaran, A., Lyu, J. "Implementation of just-in-time in a small company: a case study", *Production Planning & Control* vol 8, pp 406-412, 1997.

[13] Lee, B.H., Jo, H.J. "The mutation of the Toyota production system: adapting the TPS at Hyundai Motor Company" *International journal of production research* vol. 45, pp 3665-3679, 2007.

[14] Mohanty, R., Yadav, O., Jain, R.,"Implementation of lean manufacturing principles in auto industry", *Vilakshan–XIMB Journal of Management*, 1–32, 2007.

[15] Mottershead, D.,"Introducing lean manufacturing at ESI*", IEEE*, pp. 448 vol. 441, 2001.

[16] Kasul, R.A., Motwani, J.G., "Successful implementation of TPS in a manufacturing setting: a case study", *Industrial Management & Data* Systems, pp 274-279, 1997.

[17] Ishikawa, K., Lu, D.J., "*What is total quality control?: the Japanese way*", Prentice-Hall, 1985.

[18] Courtois, A., Martin-Bonnefous, C., Pillet, M. "*Gestão da produção*", Ed. 6. LIDEL, 2006.

[19] Bicheno, J., "*The New Lean Toolbox: Towards Fast*", Flexible Flow, pp 212, 2004.

[20] Rother, M., Shook, J. "*Learning to see: value stream mapping to create value and eliminate mud*", Productivity Press, 2003.