Achievements and drawbacks of a PPC software implementation in a Brazilian Printed Circuit Boards manufacturer

Neemias de Macedo Ferreira[1]
1 - CEETEPS - Centro Estadual de Educação Tecnológica Paula Souza
neemias.ferreira@gmail.com
Maria Lúcia Pereira da Silva[1,2]
2 – School of Engineering, University of São Paulo
malu@lsi.usp.br

Abstract

Printed circuit boards (PCB) are essential in electronic devices, therefore this paper evaluates the results achieved and the drawbacks faced after the implementation of a standard planning and production control software in a Brazilian PCB manufacturer focused in small batches and prototypes production, inside a quick turn production environment.

Keywords

Printed Circuit Board, Planning and Production Control, Software

INTRODUCTION

Among the areas where innovation factors, green economy and less environment impact work together in a beneficially way, electronics is the most prominent. As mentioned by Lovelock (2006), the planet's lack of sustainability would be more critical without the tools made available by this sector.

One of the tools made available by electronics that became a customary practice, it's a planning production using software, mainly ERP (Enterprise Resource Planning) software, with focus in cost and raw material utilization. However, it's possible to find many problems during the use of the software. In a study performed by Saccol *et al.* (2004), has been analyzed the impact of using and the no-adoption of ERP in 500 best and better companies categorized by Exame Brazilian magazine in 2000. Although there's an impact in competitiveness and lead time, ERP adoption leads to some risks, whereas many ERPs didn't deliver the promised results. Furthermore, the limited flexibility makes difficult the production control utilization, and its cost, often, is prohibitive for medium and small companies.

The difficulties for direct utilization of ERP software, start in development and/or customization of software tools specialized on operational level, and mainly based on planning and production control. As stated by Boiko *et al.*(2010), the common choice made by small industries in Brazil was the software named Preactor®.

This paper aims to show a case study in an Electronic manufacturing area, focused in Printed Circuit Board (PCB) production. This area is *sui generis*, because this industry is underestimated, although PCBs are present in every electronic equipment. On the other hand, the study of software influence in other productive areas from electronics is common (Jabbour and Jabbour; 2012).

In this scenario, this paper aims to evaluate the results achieved and the drawbacks faced after the implementation of a standard planning and production control software in a Brazilian PCB manufacturer.

THEORETICAL FRAMEWORK

Production in electronics can't give up controls and optimization by using software, and it's been a long time, ERPs is widespread in all over supply chain, included in Brazil (QUEIROZ E SILVA; 2007). Inside electronics, a relevant but overlooked area is Printed Circuit Board (PCB) production. For this area, even if internationally used, management software has shown peculiar difficulties. In 1999, Ip *et al.* suggested MRP software, predecessors of current ERPs, integrated to quality systems to improve productivity and performance. So, the purpose of adapting software in order to get a better process description, could add other indicators as inputs and outputs, getting process statistical data (Martinek, 2004).

PCBs have unique features in production terms that make ERP software hard to use. According to Oliver *et al.* (2005), technical features or attributes of the product are in wide number and difficult to standardize. To exemplify, it´s possible to mention type of base laminate, surface finishing, minimum track width and space, artwork size, layer count, number of drill holes and special requirements that can't be listed to the production order. Choi *et al.* (2006) address this issue by using workflow method. Small and Medium companies could make use of this resource, because an intermediary level is created between ERP and the shop floor. HP® got similar results in a PCB production line (Chen *et al.*, 2012) integrating its systems to ERP. Main difficulties about PCBs in production line were high complexity, small batches, custom products, short life cycle, design transfer needs among international factories.

Production optimization worries by using scientific tools isn't new. Questions like bottleneck highlights, cost reduction and get production line more and more balanced are study objects over the past decades (Batalha, 2008; Taylor, 1990). However, due to the high innovation rates and changes in this new millennium, competition gets intense and requirements also get tighter. Companies, to adapt themselves, had to offer a wider variety of products, and because this they became more flexible. Customers also require less time to deliver and quality-assured products. In a flexible and diversified product environment, besides time to deliver reduction, companies face the strong Asia competition. Due to this, the machinery used must be adapted to, even producing in a flexible way, assure low cost. In this context it is expected, with in situ and online controls, optimization of the planning and production control by software.

Manufacturing process are usually complex and need to be organized in a systematic way, in order to achieve high efficiency levels. If a change is made, as small as it could be, impact in the whole system: costs, raw material due dates, stock levels, everything in a production line will be changed (Rodic and Kanduc, 2015). This way, according to Nunes *et al.* (2009), a good planning and an efficient schedule are basic requirements to increase the company competitiveness, and make possible to get advantages like the right delivery date and idle resources reduction. Increasing productivity from better process efficiency is a key to any organization that wants to survive and overcome its competitors, adding value to customers. Therefore, Planning and Production Control (PPC) is the whole activity and operations connected inside goods and services processing, changing a status or condition of primary resources (inbounds), leading to a transformed products or a new status (outbounds) (Gaither and Frazier, 2001).

Fernandes and Godinho Filho (2007) divided PPC in two concepts: Production Planning (PP) and Production Control (PC). The first is related to medium term activities, and the second, to short term activities. However, for this study, it´s considered only short term activities, because the company studied has features that makes the work in process (WIP) dynamic and changeable every day. In this case, as Fernandes and Godinho Filho (2007) mentioned, short term controls consist of adjusting the material flow in a production system by information, control rules and decisions to execute in a scheduling way to be inserted in the production line. Production control includes four activities, to schedule line focused in the final quantities, organize material needs, control purchasing and production orders besides scheduling jobs in the machines.

According to Mesquita and Santoro (2004), analytic methods to support decision in the production planning process were weak in the beginning of the 20th century and the classic optimizing models application were not known yet. With the advent of MRP (Material Requirements Planning), which helped in the production execution, lead times management and raw material storage, MRP II (Manufacturing Resources Planning) has emerged, and it started to analyze, besides material needs, production line restrictions, as well as company financial resources. It leaded to a new category of software, ERP (Enterprise Resource Planning), merging the whole database from a company, i.e. accountability, sales, production, engineering, purchasing.

Although this class of software is necessary, the expressive amount of items to be controlled makes the ERP software operation almost impossible to customize due to the need of suppling information to the entire company. Thus, this integration can lead to a loss of focus on Planning and Production Control. Therefore, rather than helping the manager to make better decisions quickly, it could lead the management to a wrong way.

Nonetheless, there is a kind of decision-making software available in the market, named APS (Advanced Planning and Scheduling), focused on optimization issues and found in the production management process. Each company must choose the software in according to the production line features. To guide a software choice, MacCarthy and Fernandes (2000) mentioned twelve production line items: repeatability level, company size, response time, automation level, product structure, customization level, number of products available, layout, intermediate storages, types of flow, mounting types and work organization types.

Printed Circuit Board Production

PCBs are found in every electronics and its market is globalized. China is the biggest player, and Asia is accounted for 43% of global revenues (WECC, 2013). Globalization, in turn, requires production efficiency, cost reduction, short time to delivery and good quality. Brazil has good quality and short time to delivery, because logistics is the differential if compared to Chinese alternative (Carmo *et al*., 2014; Oliveira *et al.*, 2014). On the other hand, the prompt consequence is a ready machinery adaptation to a flexible production line, low cost, and make possible to produce a wide range of goods.

Womack *et al.* (1992) says that products can be classified by make-to-stock (MTS), considered standard products and stored for a future request from a customer, and make-to-order (MTO), produced by customer request and they are not stored and will not be used by a different customer. Printed Circuit Boards are MTO products, because each circuit has specific features to be used, and above all, there are a lot of different boards produced in the same time. The types of PCBs can be Single Side (there's circuitry in only one side of the board), Double Side (Circuitry in the top and bottom side of the board), Multilayer (Circuitry in top, bottom and inside the board), Flexible (produced in a flexible material) and Rigid-Flex (a rigid board connected structurally to a flexible one). Moreover, PCBs combines chemical, mechanic and photographic process with CAD/CAM programming and different production technologies.

METHOD

This paper used as methodology a case study, following the steps proposed by Yin (2005). First, the study must be prepared, from the theoretical background. In this step it has been defined the factors that would determine the choice about the company that will be studied. A survey has been made based in the priority keys that academy consider choosing a PPC software.

The second step from Yin´s case study methodology is a case selection and data preparation from the goal set. It requires variable definitions to be considered. Then, in a non-structured survey, companies have been selected considering their influence in the Brazilian market and the software used to control and planning the production. As Boiko *et al*. (2010) mentioned, one of the requirements to select companies is the use of Preactor®, due to its efficiency to make PPC.

The company selected was Micropress LTDA due to not only the above reasons but also the existence of a previous study in this company made by Ferreira and Silva (2015) that could be helpful to understand the environment. It's a high technology company, with approximately 1500m² of built area and 50 workers. Established in 1986, it has focus on prototypes, small and medium batches, its products are make-to-order and it is able to produce from Single layer up to 16 layers, with blind and buried vias. Micropress has a flexible production line, that makes a quick turn production, and the customer can get the boards requested within 8 hours. One of the indicators shows a 95% of punctuality, and the maximum delay is only one day. Besides ISO 9001:2008 certification, Micropress is the only Brazilian PCB manufacturer able to produce to INPE (Brazilian Space Research Program), in accordance to IPC A-600-H, 6012C in the 3/A requirements.

To better understanding, it will be presented the case study results in 5 distinct parts. Initially, by keywords research using Google Scholar®, it's possible to verify how academy considers software utilization in the PCB area. Following, the company situation before this study, and its evolution, that leaded the company to look for PPC software. In a next phase of this study, it´s presented the company operation features that need to be supported by the software. Based on this, how the company selected the software and, a brief description about its implementation, achievements and drawbacks.

RESULTS

<u>Search by keywords using Google Scholar®</u>: citations related to assembly and mounting have been excluded because they are not a part of this study scope. The answers are described in table 1, where it´s possible to find an evolution about *Printed Circuit Board* citations, showing that beyond an important product from a technological point of view, the PCB technology research level and development have increased along the period covered by this study.

The same could be seen to the global demand for PPC software, doesn't matter the kind of industry, as seen in the graphic 1, that shows the number of citations for *Printed Circuit Board*, divided by 1000 to better visualization, and the number of citations for *PPC Software*. It is possible to verify there are few or no information about software for production planning to PCB industry. Furthermore, there is a division between ERP increasing and its utilization in PCB, presented in the graphic 2, that makes a relationship between ERP and PCP software.

Therefore, from 2007 to 2009, when dedicated software are spread in the market, there is no likewise attention to PCB area. Thus, considering literature review, commented in this case study and the situation observed for this research, it's justified to better comprehend the software utilization in the PCB production and control.

Table 1 – Keyword search by year - Source: Google Scholar®

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Printed Circuit Board	3250	3500	4170	4520	4980	5280	5870	6320	6690	6860
PPC Software	647	897	906	1020	1160	1180	1230	1390	1430	1350
"production planning and control" software	479	663	654	729	860	828	888	1030	1060	930
"Printed Circuit board" "Enterprise Resource Planning"	7	6	13	7	12	9	8	12	12	7
"Printed Circuit board" "production planning and control"	4	6	9	7	3	6	10	6	9	7
"Printed Circuit board" "production planning and control" "Software"	2	4	8	5	2	4	7	5	8	6

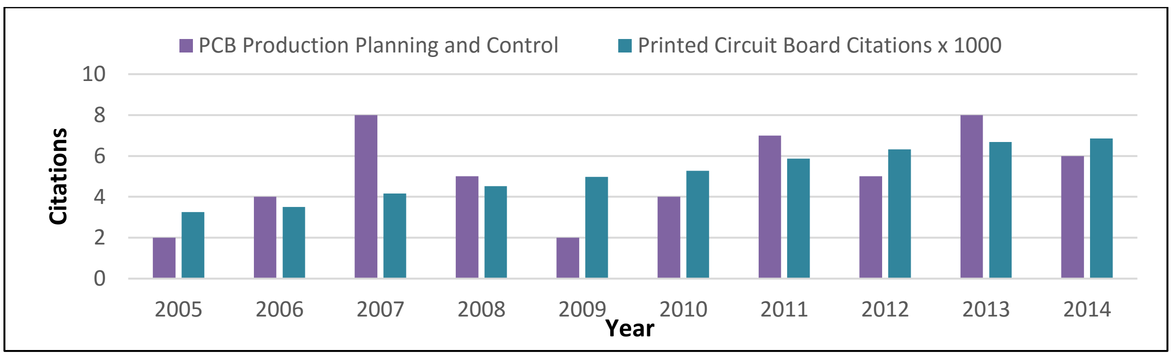

Figure 1 - "PCB production Planning and Control" and "Printed Circuit Board" Citations (x1000)

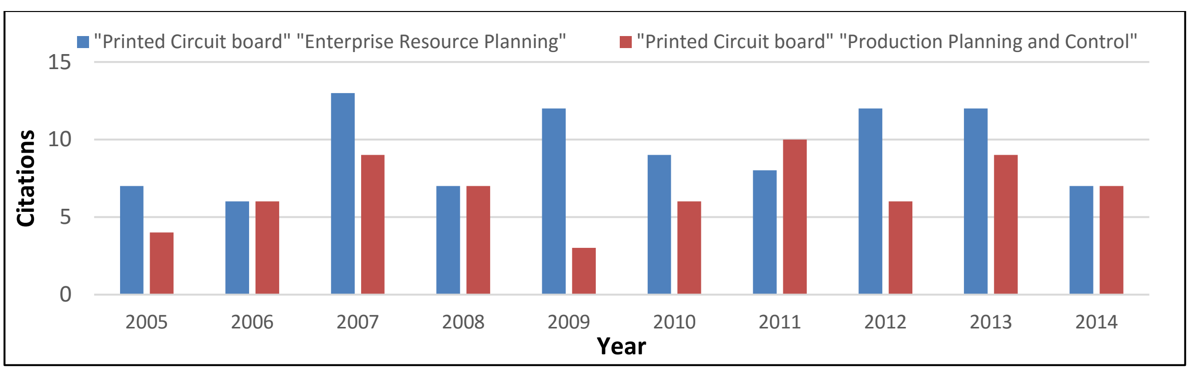

Figure 2– Relationship: PCB "Enterprise Resourcing Planning" and "Production Planning and Control"

<u>Case study and its initial characterization</u>: The chosen company for this study should meet to certain conditions, examined in the beginning of this paper. By technical visit, the company Micropress was chosen to be studied.

The flowchart of company's productive process has already been registered and studied by Ferreira and Silva (2015); therefore, in this paper, just for a better understanding, it´s presented in figure 3 a schematic flowchart of 2 layer printed circuit board.

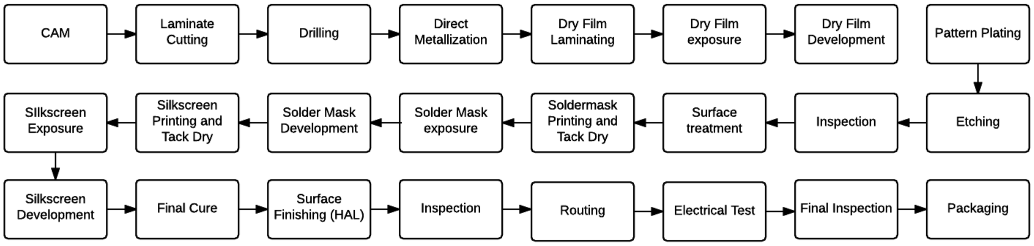

Figure 3 - Basic Flowchart for a 2 layer PCB production. Source: Created by authors

The company used to plan and control the production by spreadsheet application with basic programming resources, that met the control needs in that time – low production – but it didn't have a precise control in case of normal market fluctuations, and much less a precise production time forecast for the batches in all over the production line. All these controls were made by Production Scheduler.

<u>The major drivers for PPC software acquisition decision</u>: By non-structured survey made to company managers and directors, the history of buying the software license was obtained. As the demand for PCBs increased in 2007, as shown in the figure 4, it became very difficult to plan and control the production using the spreadsheets previous mentioned. It wasn't possible to know easily the batches position in the production line, and even to foresee if the mix of operations related to batches in production would allow to a specific batch to be delivered in the date set. In this context, it was possible to conclude, by the company's directors that the tools used before were not able to meet the new scenario and a PPC software would be the suitable investment to do, and would make the customer support more reliable. The contract renegotiations shown in the figure 5 is also an indicator of process in that time.

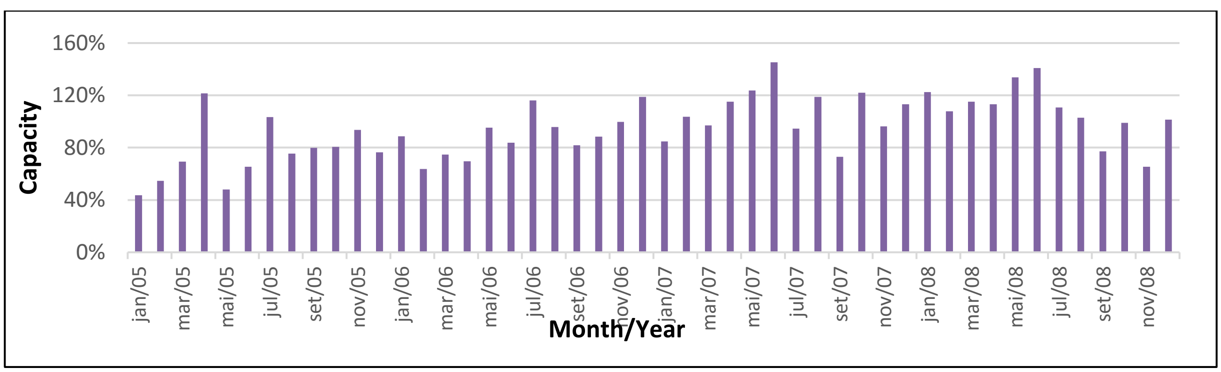

Figure 4 - Factory Capacity Used from 2005 to 2008 - Source: Created by Authors

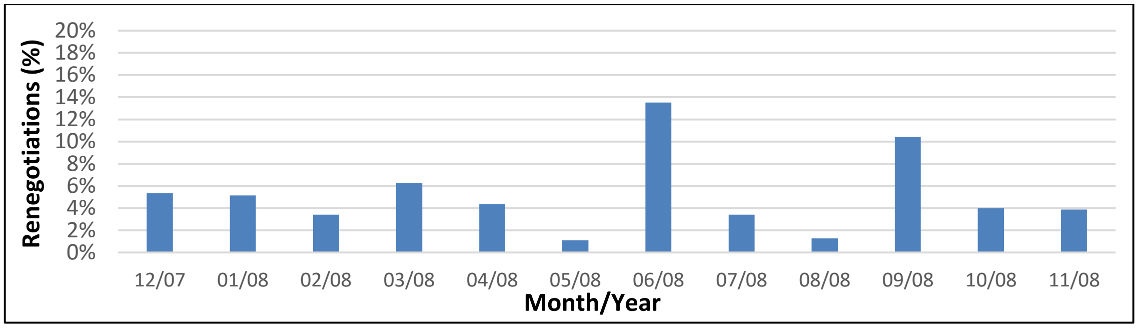

Figure 5 – Contract Renegotiations registered from Dec/07 to Nov/08 – Source: Created by Authors

Requirements engineering and PPC software choice: The entire comprehension about how the software was chosen has been obtained by documental analysis and non-structured survey made to company´s manager and directors. The main company´s profile are small batches, prototypes as well as pilot batch made to order, in the shortest production times found in Brazil (8 hours). The amount of process by which the boards are submitted is long and complex but, with high technology combined with ready customer support, the production time is a competitive advantage.

In accordance to the production supervisors, in this context, there is no such range to tricks and the tools used made that the execution of scheduling was done from subjective criteria, making difficult the build of scenarios and simulations to make a decision. Besides, tools are not sufficiently quickly to face unexpected situations like new orders in quick turn, very often in the market the company runs.

In short, supervisors expected that the software improve capacity utilization to meet the demand, reduce the time spent for PCP team in the planning, scheduling and rescheduling activities; reduce the delay in the orders as well as its lead time; make available precise and updated information about production dates; make the scheduling based on conditions associated to productive process; line and resources balanced allowing a quick production adjustment in according to the demand, production conditions and service policy; follow the scheduling execution and make available ready to use information about orders' status, make easy to identify bottleneck in the operation; Show the programmer the rescheduling consequences; improve overtime analysis and its utilization as well as shifts, equipment and human resources. It was also expected that the software could make production dates simulations by sales department before the deal, and in the end, the better price, in accordance with these needs.

As the company didn't have specialized personal to make this research, a consultant has been hired to make a market research to find one software that would meet the requirements as well as reduce or eliminate the spreadsheets used in the production. After several meetings and evaluations by the company´s direction, and some information about PPC software users, it has been decided by Preactor®, because this software meets the requirements in an affordable cost.

The software implementation: a comprehensive understanding of how the software was chosen has been obtained by documental analysis and non-structured survey made to company´s manager and directors. Software was chosen, and after the whole business procedures and project management, the implementation has begun. During 6 months, there was a productive process understanding, and so, the software initialized its operation.

To start the software implementation, it´s been established the crono-analysis process. The process production time wasn't known in detail. These process times – those that are not dependent of the board´s features - have been extracted and fixed to be inserted on the system as a parametrization to make a production recipe. To make the exact production time calculation for a batch, it's necessary to extract features from the board's project, like minimum hole diameter, panel size, minimum track width and space, routing extension, among others. These data are extracted from the project by CAM area. Preactor® imported these data and based on the suitable recipe, a timeline was created for this batch from the first process until packaging. It happened the same way for other batches.

As batches were inserted in the master production plan, there were new calculations and scheduling in accordance with each batch and its features. Based on this scheduling, a list of priorities has been provided in key areas by a net of computers installed only for this application. All the computers were connected to Preactor®.

Drawbacks and Achievements analysis: the chrono-analysis process was one of the items that changed the planning and production control structure. It was possible to know the time spent for each step of the process in a detailed way, and reduce the waste of time between each step. However, each batch has features that can lead to an impact in the whole time of production. It can be organized by the software to reduce unforeseen events in the planning.

One of the needs to be met by the software was a possibility to simulate production dates by sales department during a quotation process. There wasn't a native tool by the software able to do this simulation. Despite some developments based on customizations have been done, the utilization wasn't practical, in accordance to the company´s director because it made quotation process slower. So, it wasn't possible to make a preventive action during the deal with the customer, offering reliable dates of production.

The software needed an operator. This person minimized the "production engineering time", however, the application doesn't work by itself. Besides, there was no solutions suggested by the software and the critical areas (a specific bottleneck, for instance) weren't showed clearly. However, the master production plan visualization could lead to a review and make adjustments in an empirical way until get a solution for the situation.

One of the customizations made was the priority list in computers installed in key areas. This way, workers could know clearly the priority in real time. The scheduling done by Preactor® was transmitted to all machines. It made possible both a key process monitoring and an easy evaluation about what were the major problems related to a waste of time in the operation.

Preactor® didn't balance the line; some process has over production and the following process won't get the production sent before. It made the work in process higher and difficult to see in the system and in loco.

For the company, the indicator of renegotiations is related to the moments where the inevitable delay required a renegotiation and a new production date to be scheduled, that's why it´s important to strategic objectives. It´s possible to compare figure 5 to figure 6 results and the apparently worsening immediately to the software implementation is related to the adaptation time (6 months). However, there are big fluctuations over the time. Such oscillations reflect higher production times (figure 4). Then, the software is difficult to use in very short time conditions, probably due to not balancing the line.

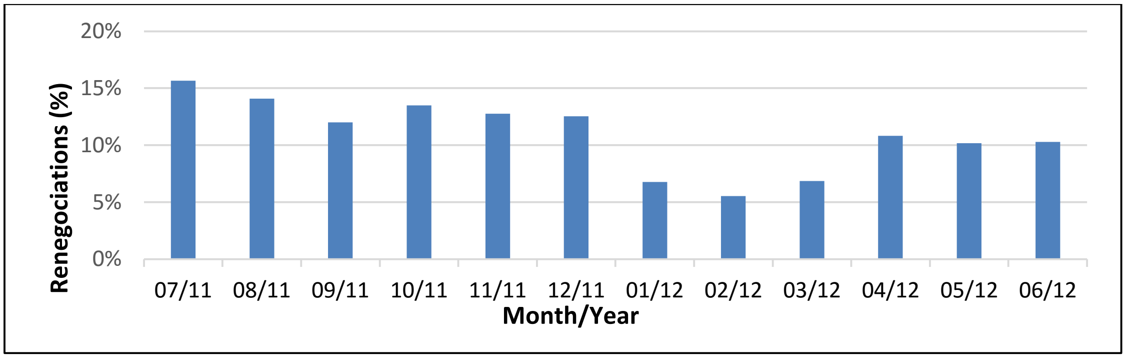

Figure 6 - Contract Renegotiations registered from Jul/11 to Jun/12

CONCLUSION

This paper showed that the software utilization in the PPC could offer good results. However, it was possible to verify that there is no PPC software suitable to Printed Circuit Board area, and not only in accordance with the Google Scholar® results but also by the issues faced in this case study. Therefore, there is a lack of technology in this field in Brazil and, maybe, it is a global need. This is critical, for instance, on the company studied, which is a leader in prototypes and small batches and with an advanced operation management, since software implementation could be an excellent way to improve the punctuality of PCBs produced.

Therefore, it´s necessary to test controlled ways to manage the PCB production. One of the concepts that could be studied is the relationship between Flow shop and Job shop. Once the entry of batches is controlled, it´s possible to plan the whole system by a big batch. Thus, a software would be necessary just to help us to make calculations instead scheduling each process and batch by time.

Bibliography

BOIKO, T. J. P.; MORAIS, M. F.; VAROLO, F.W.R.; TSUJIGUCHI, L.T.A. 2010 Uma análise dos trabalhos em programação da produção publicados no Brasil envolvendo estudos de casos. *XXX Encontro Nacional de Engenharia de Produção*.

CHEN, S.; CHANG C.; LIU K.; CHEN; H.; YEH, S. 2012. Implementing the product data management into enterprises: Five Case Studies, *Australian Journal of Business and Management Research* **2**(3).

CHOI S., PARK M., LEE D., JEONG K., LIM S. 2006. A Conceptual Framework of an Advanced Planning and Scheduling System for Printed Circuit Board Manufacturing Lines, *Asia Pacific Management Review*.

FERNANDES, F. C. F.; GODINHO FILHO, M. 2010. *Planejamento e controle da produção: dos fundamentos ao essencial. São Paulo*, Editora Atlas, São Paulo, Brasil.

FERNANDES, F. C. F.; GODINHO FILHO, M. 2007. Sistemas de coordenação de ordens: classificação, funcionamento e aplicabilidade. *Gestão & Produção*, **14(**2): 337-352.

FERNANDEZ-FLORES, O., SPEER, T., DAY, R. 2009. Design Considerations of Scheduling Systems Suitable for PCB Manufacturing, *World Academy of Science, Engineering and Technology*, **4**.

FERREIRA, N.M., SILVA, M.L.P. 2015. Dificuldades e limitadores da otimização da produção de placas de circuito impresso, *X Workshop de Pós Graduação do CEETEPS*.

GAITHER, N; FRAZIER, G. 2001. *Administração da produção e operações*. Editora Pioneira, São Paulo, Brasil.

JABBOUR, A. B. L. S.; JABBOUR, C. J. C. 2012. Lançando luzes sobre a gestão de operações do setor eletroeletrônico brasileiro. *Revista de Administração Pública*, **46**(3): 817-840

LOVELOCK, J.E. 2006. *A Vingança De Gaia*, Ed. Intrínseca, Rio de Janeiro, Brasil

MACCARTHY, B. L.; FERNANDES, F. C. 2000. F. A multi-dimensional classification of production systems for the design and selection of production planning and control systems. *Production Planning & Control*, **11**(5): 481-496.
MENEZES, A. M. P. B; SOUZA, I. F.; DUARTE, F. 2005. Análise do software livre como uma alternativa de TI para as PMEs *XXV Encontro Nacional de Engenharia de Produção*. – 4367–4374
MESQUITA, M. A., SANTORO, M. C. 2004. Análise de modelos e práticas de planejamento e controle da produção na indústria farmacêutica, *Revista Produção*, **14**(1)
NUNES, D. M., MELO, P.A.C., NIGRO, I. S. C. 2009. Planejamento, programação e controle da produção: o uso da simulação do Preactor em uma indústria de alimentos. *XXIX Encontro nacional de engenharia de produção*.
RODIC, B., KANDUC, T. 2015. Optimization of a complex manufacturing process using discrete event simulation and a novel heuristic algorithm; *International Journal of mathematical models and methods in applied sciences*, Vol 9.
SACCOL, A.Z.; PEDRON, C. D.; NETO, G.L.; MACADAR, M. A.; CAZELLA, S.C. 2004. Avaliação do Impacto dos Sistemas ERP sobre Variáveis Estratégicas de Grandes Empresas no Brasil, *RAC*, **8**(1)
SILVA , F. M., FERNANDES, F. C. F. 2008. Proposta de um sistema de controle da produção para fabricantes de calçados que operam sob encomenda, *Gestão & Produção*, **15**(3): 523-538.
SVISZT, O.; MARTINEK, P.; SZIKORA, B. 2005. Typical features of printed circuit board production enterprise resource planning systems *28th International Spring Seminar on Electronics Technology.*
WECC Global PCB Production Report For 2013, 2014.
YIN, Robert K. 2005. *Estudo de Caso: Planejamento e Métodos*, Bookman, Porto Alegre, Brasil