

## **IMPLEMENTATION OF THE PULL LEVELLING PROJECT IN A CAR RADIO ASSEMBLY FIRM**

**Celina Afonso\*, Anabela Alves\*\***

Universidade do Minho, Escola de Engenharia, Departamento de Produção e Sistemas  
Guimarães, Portugal,

\*Email: [celinalma@gmail.com](mailto:celinalma@gmail.com); \*\*Email: [anabela@dps.uminho.pt](mailto:anabela@dps.uminho.pt)

### **SYNOPSIS**

This paper presents some results from the implementation of pull levelling strategy between the final assembly lines and the Original Equipment Manufacturing (OEM) clients of a car radio assembly firm. In order to respond quickly to the clients the firm maintained a stock level of, approximately, ten days of finished product for each client. This implies high costs for the firm. The implementation of the pull levelling strategy reduced these costs and increased the flexibility approaching the production to the demand, in quantity and in diversity, required by the clients. Additionally, this implementation permitted the detection of deviation, identification of problems, creation of standards and continuous improvement, stabilization of the upstream processes and the reduction of components stock. The performance indicators used by the firm to measure the performance of this implementation were the fulfillment (the achievement of the production levelling plan supplied by the Production Planning Department), the stock level, the Every Part Every Interval (EPEI) number and LIWAKS (accomplishment of the due date negotiate with the client).

### **1. INTRODUCTION**

The implementation of the pull levelling strategy was a partial objective of a project that this firm initiates a few years ago. The main objective of this project is the adaptation and implementation of techniques, tools and strategies derived from the Toyota Production System (Monden, 1983), more known, nowadays, as Lean Manufacturing (Womack et al., 1990, 1996), to the production system of the this firm. Others tools and strategies, already implemented by the firm, were, for example, the SMED and Quick Changeover (Costa et al., 2008), the Kanban system and production cells (Cardoso et al., 2008 and Oliveira and Alves, 2009).

In the Toyota Production System (TPS) the pull system is defined as a continuous flow of products at the factory in order to adapt to changes in demand. The concretisation of this idea is achieved by the JIT production that could be synthesized as produce only the necessary amount needed and on the time required. The result is a desirable reduction of stocks and of the work force with consequent increase in productivity and cost reduction. Liker (2004) defines levelling production as a smoothing out the volume and mix of items produced, which means a little variation in production from day to day. So, levelling out the schedule is a foundation for flow and pull systems and for minimizing inventory in the supply chain.

The levelling strategy was already implemented in the firm but in a push environment. This causes some problems being the main problem the finished product stocks high costs. So, the objective of the project which results are here presented was transforming the push

environment into pull environment. Other important goal of the project implied the support of the development of pull tools for supermarket management, the training of the users of these tools and the evaluation of the project indicators. These indicators were obtained through the comparison of the actual situation with the previous one, in what concerns to the production aspects and the production process.

This project, in a first phase, was implemented in one of the production lines. This line was chosen because had two finished product flow circuits (the most complex scenario), but was the most stable comparing with others. These aspects make this production line the best one for a successful implementation of the project.

This paper is structured in 4 main sections. After the introduction, in section 2 a brief reference to the methodology used in the research developed in the firm is presented. The section 3 describes the diagnosis of the production system existing in the company prior to implementation of the pull levelling production, the planned actions, the actions taken in order to implement the pull levelling project and the results evaluation. In Section 4 some final conclusions are presented.

## **2. THE ACTION RESEARCH METHODOLOGY**

As a final project of Integrated Master Degree of Industrial Management and Engineering, the first author of this paper was included in a team responsible for the implementation project of the pull levelling between the final assembly lines and the warehouse of finished products for clients OEM. The main objective was to reduce the stock costs of finished products. The activities for the project were developed through observation, analysis and participation in the daily events in the final assembly line selected for the implementation of the pull levelling, adopting what has been, normally, called Action Research methodology.

This methodology appeared to be adequate mainly due to the research nature, because the author/researcher, within the industrial environment under study, was actively involved in the project, investigating the processes on the ground and possible improvements to be implemented. According to Rapoport (1970, cited in Macedo et al., 2004), Action Research methodology is qualitative and the researcher role, besides being an active part in implementing the research, is to analyse and evaluate the results obtained by the changes introduced in the subject under study.

Gilmore (1986, cited in O'Brien, 2001) defines Action Research as “*Action research...aims to contribute both to the practical concerns of people in an immediate problematic situation and to further the goals of social science simultaneously. Thus, there is a dual commitment in action research to study a system and concurrently to collaborate with members of the system in changing it in what is together regarded as a desirable direction. Accomplishing this twin goal requires the active collaboration of researcher and client, and thus it stresses the importance of co-learning as a primary aspect of the research process.*”

This methodology comes from a methodologies family that uses the action (or alteration) and the research (the understanding) simultaneously. Initially, it is executed a cyclic or a spiral process that switch between action and critical analysis and, after that, occur a data and methods understanding that continually would be improved (Dick, 1999). The cyclical nature of the action research process includes five steps: diagnosing, action planning, taking action, evaluating and specifying learning.

In the first step it is essential to identify the problem and collect data to search the solution or solutions. The second step is the planning of the actions to develop. Then, one of these solution is chosen, the third step, and is followed by an evaluation of the results obtained, the fourth step. Finally, the fifth consists in verifying if the problem was solved or not. In this case the process begins until the solution for the problem is found.

The problem was identified by the firm as being the high costs of the finished product stocks and it was aware of the need to improve this. Thus, the work developed was to respond to the following research questions:

- How was attained the production levelling in the push environment?
- What could be done to implement the production levelling in the pull environment?
- How the levelling pull implementation could improves the performance indicators?

### **3. THE DEVELOPED WORK**

The work was developed following the methodology presented above. This work starts with the integration and follow-up of all operations performed in the area where the project was developed, in order to understand the system operation. Being so, it was possible to implement the production levelling, in a pull environment, for direct delivery clients and advanced warehouse clients, both being OEM clients. The critical analysis of this operation allows the identification of problems and the presentation of solution proposals to address them. After being approved by the enterprise responsible people, these solutions could be implemented.

The problem was identified, being necessary to diagnosis the situation and collect the data. The relevant data to the problem is described next, followed by the critical analysis. Further, were presented the proposals presentation and their implementation. The performance indicators were measure and results were discussed in order to implement the procedure to the remaining assembly lines.

#### **3.1 Description and characterization of the industrial setting**

The industrial setting of this study belongs to a well consolidated firm which main product is the car radio for the automobile industry. The production process is subdivided in two sectors: Automatic Insertion (IA) and Final Assembly (FA). The sector of Automatic Insertion is characterized by the use of technology that automatically inserts the components Surface Mount Devices (SMD) of small size (0.5mm), into the surface of the Printed Circuit Board (PCB). Then, the PCBs are moved by a transporter (named milk-run) to the supermarket on the same floor. The PCBs are moved to an area of transition processes which are properly identified and obey to the First In First Out (FIFO) strategy. However, there is implemented between the IA and the supermarket of PCBs a Kanban system to produce only what the final assembly need, otherwise production does not occur in order to do not increase the stock.

At the beginning of each line of IA, there is a sequence of Kanbans to place the sequence by which it will produce the PCBs in the IA. The Kanbans of IA are different from Kanbans of the Final Assembly and have taken care to examine the whole process and make Kanbans according to the needs of the information required. The Kanbans that cover the entire production process, from the IA to final assembly are displayed in the back of containers

which have the function of transporting the PCBs after leaving the IA. The containers are used to transport the main motherboards and the service boards according to the amount of their Kanban production. In IA, the Kanban is posted in containers, and goes through the various processes to be consumed in FA. After that, the Kanban returns to IA and a new order of production is given for the restore of the supermarket. This cycle is repetitive and imposed by the consumption board final assembly. Subsequently, the PCBs are transported by milk-run, when required, to the area of Final Assembly. So, there are two cycles of milk-run supply of materials to the lines, one for the supply of PCBs from the supermarket to the production lines and another cycle of supply of materials from the warehouse of raw materials to the production lines, being the responsible for this the Internal Logistics.

After the arrival of materials and trays from the supermarket to the lines established at the factory, it is the beginning of the process for the final assembly. The Figure 1 illustrates the broad outline of the production process in the final assembly lines, with the main sections: a manual insertion, welding, electrical test, final assembly and final inspection.

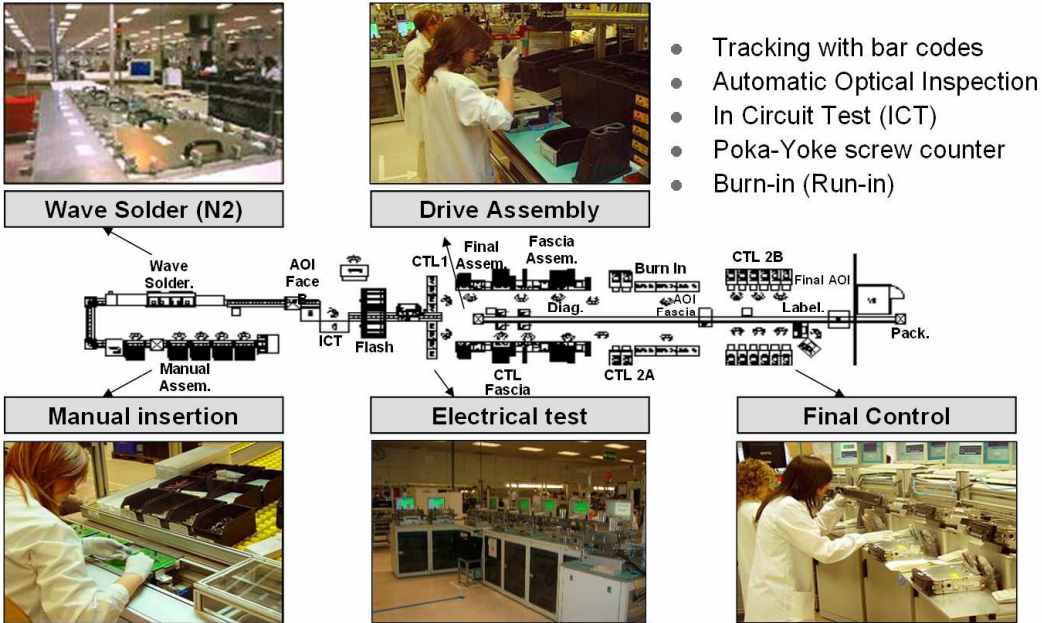


Fig. 1 – Main sections of the production process for the final assembly lines

The operative sequence depends on the specification of each PCB that can contain only SMD components or SMD and Plated Through Hole (PTH) components, and it is this feature that dictates the flow of materials. First, it is inserted manually the components PTH in PCB, through a process of welding the boards of these components by wavelength. After assembly the larger components, continues to sitting the test, first there is the In Circuit Test (ICT), used to test the behaviour of welded components in PCB through the transmission of test signals, then the functional test, which verifies the functionality of the car radio produced (final check). Finally, the car radios are packaged and sent for dispatch.

**3.2 Diagnosing the process**

Before implemented the pull system, this firm had implemented the system of the push levelling in final assembly lines. The pull system was, only, implemented between the section of Automatic Insertion and Final Assembly and between local suppliers and the warehouse of raw material. However, between the final assembly and expedition of finished product for the

client, company's objective was also to implement the pull system of production. For the OEM customers, the coverage of stock of finished product was 9,95 days and the lead-time (LT) was 45,82 days.

The process of the production levelling begins with the levelling plan, daily placed in the box Logistics. Then, the plan is placed daily on the levelling production board by production department, adjusting the plan to indicate the production in the previous day. Eventually, may have occurred that the production plan of the previous day has not been met. After being set a schedule of daily production level, the Kanbans are distributed to the 8 hours shift. Thus, the production of the quantity defined in correspondent Kanban begins when it is removed from the levelling box to the sequencer and is placed at the beginning of the final assembly board. This type of production generates large stocks of components and materials, i.e. upstream of the production process. Thus, it was important to find another solution to change this picture. In Figure 2, could be found the sequence of the levelling process carried out in the environment push.

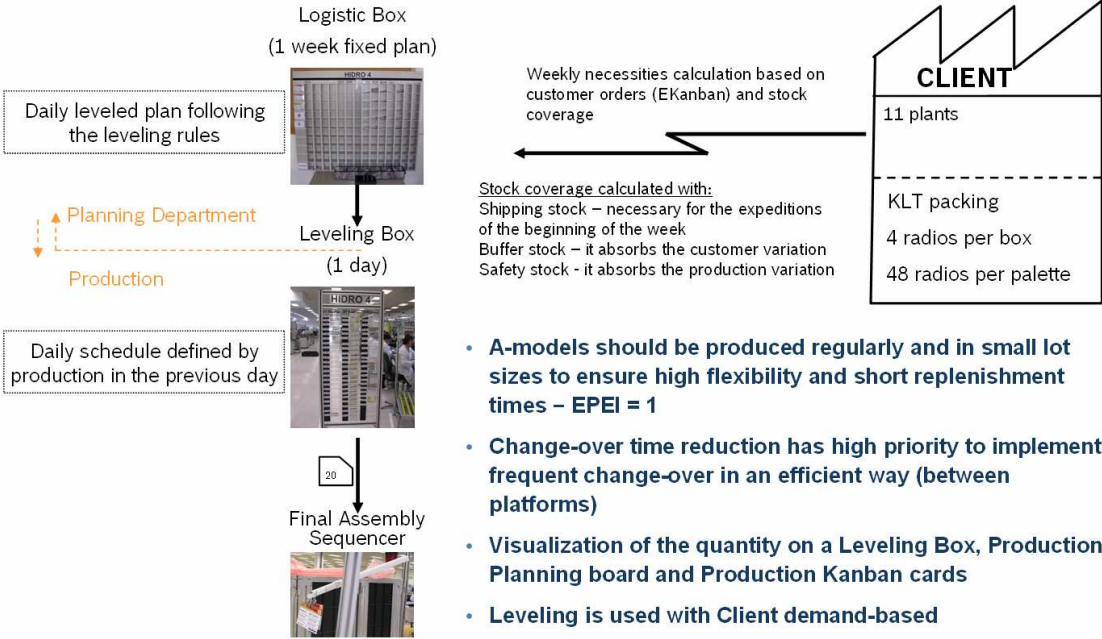


Fig. 2 – Sequence of the push levelling system

From all OEM clients of the enterprise, it had been selected the customer whose line has two finished product flows (represents the most complex scenario), one in the warehouse inside this firm and the other outside the firm named EDL, but with the most stable operation. The orders of this customer requests indicates that this do not has a great variation. These aspects make this production line the best one for a successful implementation of the project.

The indicators used to evaluate the performance of this project are to Every Part Every Interval (EPEI), the Daily Fulfillment, the levelling Fulfillment, the number of days' stock of finished products in warehouse and LIWAKS.

The EPEI is evaluated in a production line to verify the frequency of production of a specific reference A to the period of levelling considered. Also serves to assess whether or not the line is well leveled. It is considered that the ideal is that a reference A has EPEI A = 1, i.e. if the

time horizon for a week and it has five working days, then the production will have to produce in each of five days a certain amount of Kanbans for this reference.

On the Fulfillment (FF), this is analyzed in two parts, the weekly levelling, FF and weekly diary levelling, FF. The measurement of daily and weekly levelling Fulfillment aims to measure the degree of fulfillment of the plan for weekly levelling production of each final assembly line, supplied by the production planning department. At the beginning of each week, it is the evaluation of the levelling plan by measuring FF and EPEI for the week N-1 and the time horizon of this plan is one week. The weekly levelling FF compares the amount of Kanbans actually produced to the amount that was necessary to fulfill the weekly levelling plan. The weekly diary levelling FF compares the amount of Kanbans produced is equal to the amount that was pre-established plan to meet daily.

The performance measure for delivery to the customer, i.e. the fulfill of the delivery to the customer at the right quantity and delivery schedule previously established in the contract between the customer and the company is followed by LIWAKS, due date negotiated because this is an important requirement.

The different performance indicators considered before implementation of the pull levelling on the final assembly line are presented in table 1.

Table 1 –Indicators value for the 2004 year

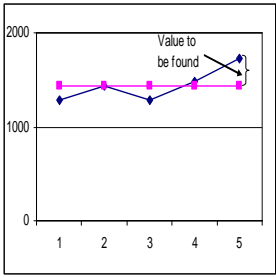
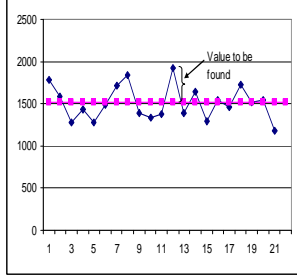
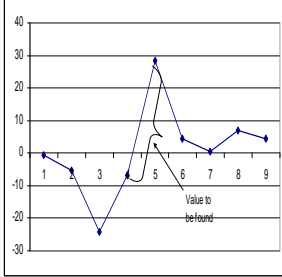
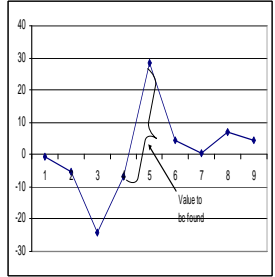
	<b>EPEI</b>	<b>Daily Fulfillment</b>	<b>Levelling Fulfillment</b>	<b>Stocks</b>	<b>LIWAKS</b>
<b>2004</b>	1,6	40%	Unvalued	11 days	88%

### 3.3 Planning the actions

The project to implement the pull levelling on the lines of final assembly was subject to several discussions and meetings. The objective was optimising the stock and produce in line with what the customer wants. The starting point for this study was to consider four levelling options: frequency for setting the output (weekly or monthly) and for setting the mix/level (weekly or daily). So after some meetings, the team work of this project set the options for levelling shown in Table 2, which summarizes the study and description of each option.

For each option was calculated the number of Kanbans for the two finished product flows considered. For the scenario of levelling to one day, weekly and monthly contract, the total number of Kanbans for the two circuits was 8,4 days and 8,5 days, respectively, being the difference insignificant. Levelling for five days, the total number of Kanbans was 9,4 days, for the two types of contract. No gain in number of days absolutely none in this case.

Table 2 – Options of levelling considered

Pull Levelling (1 day)		Pull Levelling (5 days)	
Contract		Contract	
Weekly	Monthly	Weekly	Monthly
<b>Total Demand:</b> <ul style="list-style-type: none"> <li>• Maximum variation daily demand face to average weekly</li> <li>• Stock distributed weighted by all the references</li> </ul>	<b>Total Demand:</b> <ul style="list-style-type: none"> <li>• Maximum variation daily demand face to average monthly</li> <li>• Stock distributed weighted by all the references</li> </ul>	<b>For Reference:</b> <ul style="list-style-type: none"> <li>• Maximum variation between the averages of two consecutive weeks</li> </ul>	<ul style="list-style-type: none"> <li>• Maximum variation between the averages of two consecutive weeks or</li> <li>• Maximum variation demand face to the average of the month</li> <li>• Choose the largest of the two</li> </ul>
			
Possibility of failure of the plan to 1 fixed day		Possibility of failure of the plan to 5 fixed days	

Of the four options examined initially, it was appropriate to consider only two of them to proceed with the project level: levelling one day/output fixed monthly and levelling five days/output fixed monthly. These were the best scenarios because made the system more flexible to possible changes in customer demand. Table 3 shows a study of the benefits and drawbacks of each these scenarios.

Table 3 – Levelling options at one or five days/output fixed monthly

	Levelling 1 day/output fixed monthly	Levelling 5 days/output fixed monthly
<b>Advantages:</b>	<ul style="list-style-type: none"> <li>▪ Less time to react to the variations of client;</li> <li>▪ Reduction stocks compared with a levelling 5 days.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Increased stability for the upstream stages of production and suppliers;</li> <li>▪ Less complexity of control.</li> </ul>
<b>Disadvantages:</b>	<ul style="list-style-type: none"> <li>▪ Increased complexity of control system (frequency and algorithm)</li> <li>▪ Less time for approval of the plan</li> <li>▪ Need to review the objectives stocks of raw material to support the daily variations</li> </ul>	<ul style="list-style-type: none"> <li>▪ Reaction time upper than changes in customer and consequent increase levels of stocks</li> </ul>

After analysis Table 3, it seemed that planning a product for only a day involves much more work and resource allocation. This can be avoided if the plan could be established for a longer period, e.g., five days. This also showed greater advantage for five days with a fixed monthly output due to greater stability for the upstream stages of production and suppliers as well as the lower complexity of control system.

### 3.4 Developing the action

This section sets up the implementation of the pull levelling to one final assembly line. The sequence of actions for its implementation and decisions taken during this project are described. The implementation of the pull levelling system for five days, monthly contract, was followed by several steps to achieve them.

First, it was developed the algorithm for calculation of consumption based on the formula for calculating necessary number of Kanbans. Second, it was acquired boards for visualization of level of stocks in local and EDL supermarkets. After that, the third step was to apply this system a physical system to be activated when the minimum and maximum limits of stocks were reached. It was placed on top of board visualization stocks an ANDON which have details of the client corresponding week in question and associated with each one a minimum and a maximum level of stock. Also, it was created more physical components (Kanbans) to cover the new needs. In local warehouse finished products, it was defined the footprint shelves reserved for the clients of production line studied. Finally, to make available this project, the users were trained in all mechanisms implemented and was prepared the follow up plan for implementing to others assembly lines.

The pull levelling for five days is illustrated in Figure 3, showing the sequence of processes after the implementation of project in the final assembly customer and giving an overview of the sequence of operations, the flow of materials and information involved in this project.

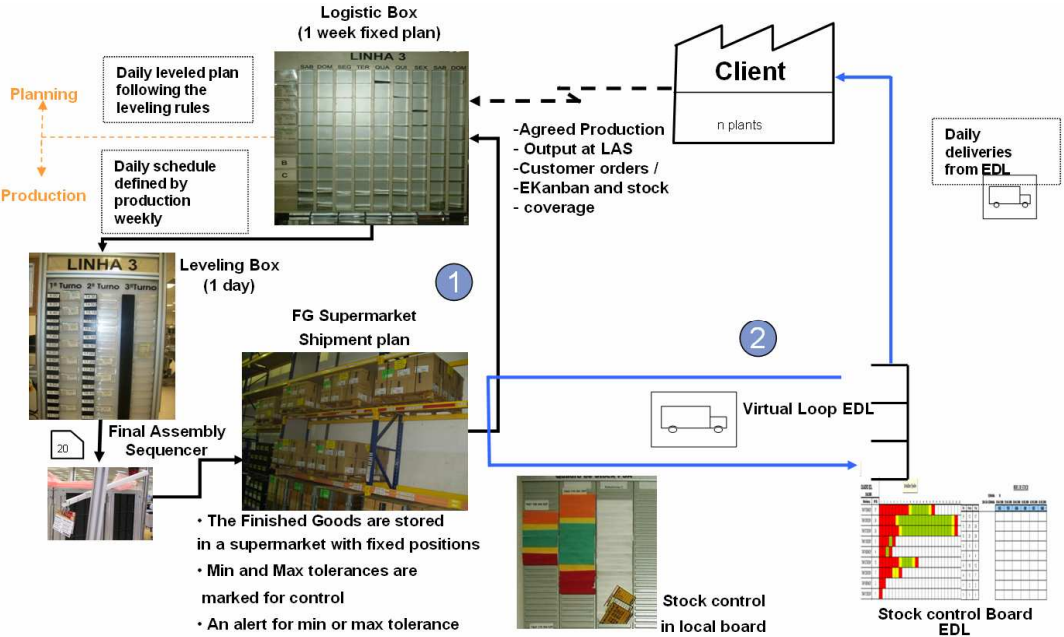


Fig. 3 – Sequence of the pull levelling system

The production planning for the week n+1 is, weekly, prepared, and the planner put Kanbans in the logistics box, now, near the assembly lines. Then, in the logistic box are placed the Kanbans corresponding to all references to be produced in one specific week. Thus, for each day of the week, are placed in this box as many Kanban cards as radios wanted to produce for the week in question, each Kanban is associated with a quantity of radios.



After this phase, daily, the assembly line supervisor schedules the cards for eight hours each shift, removing the Kanban card from the logistics box and putting them in the levelling box for producing in the next day. Thus, the following day first shift will start producing the quantity of radios for the first Kanban which is in first position of the table following the sequence of levelling previously established by assembly line supervisor. The production process begins when withdraw the first Kanban of levelling box and is placed in the sequencer at the beginning of the final assembly line. When the milk-run supplies the assembly line with the motherboards in the containers from the supermarket, transfer Kanban for the sequencer to produce the quantity of radios for first Kanban card.

At the beginning of line are located two sequencers with opposite directions. One aims to indicate what is the quantity of radios corresponding to the Kanban that comes next on line. Therefore, only after the consumption of Kanban in the first workstation at the beginning of the final assembly line, the operator puts card in sequencer at the opposite direction to the first mentioned i.e., produced Kanbans.

When milk-run arrives with PCBs and components for supply the assembly line, the operator has, also, the task of removing the Kanban produced at the sequencer and move it to another sequencer at the end of the final assembly line (packaging). After finishing the operation of packing the radios and if all of the pallet is completed, the operator removes the Kanban on line, get a bag of cash to their pockets and puts it in the bag completing this operation with the fixing of the exchange with the Kanban in its pallet fully completed and ready to go to the expedition. The next step is to remove the card of sequencer and put it in position in line because this position indicates that Kanban in line is currently being produced. If the pallet is incomplete due to a problem on the line, then the Kanban is placed on the bar adjacent to the conveyor of the finished product, in the position of the pallet until it is incomplete to full the production process for that Kanban.

After enclosed the pallet for each Kanban, the operator places the bag with the card in pallet and gives indication that the pallet is completed. Therefore, it can be moved by milk-run to the finished product warehouse. After the arrival to the store of pallets of finished product, the operator removes the Kanban that each pallet has, put it in the visualization board of stock and placed in the box for the collection of handbags. This board allows view, in real time, the level of stock of each reference to the finished product warehouse. Finally, after the submission of requests of the client, the Kanbans are withdrawn from the visualization board of stock and place in the line of requests accomplished. Weekly, at Fridays, the Kanbans in the line of requests accomplished and bags are collected and placed in the library of cards.

### **3.5 Evaluating the results**

This section presents the results of the proposed project implemented with the pull levelling production. After the pull levelling implementation the coverage of stock of finished product for OEM customers is 8 days and the lead-time (LT) is 37 days. These figures indicate that, indeed, the project has implemented substantial improvements to the system's overall business, as the lead-time and the stock of finished products were reduced. This shows that the improvements achieved it was a reduction the stock of finished products of 9.95 days for 8 days, which requires the company to reduce costs of stock associated, going into the objectives imposed. The comparison of others performance indicators (Table 4) reveals, also, improvements with the pull levelling implementation.

Table 4 – Comparison of indicators - key performance

	<b>EPEI</b>	<b>Daily Fulfillment</b>	<b>Levelling Fulfillment</b>	<b>Stocks</b>	<b>LIWAKS</b>
<b>2004</b>	1,6	40%	Not evaluated	11 days	88%
<b>2008</b>	1,07	97%	90%	9 days	97%

Thus, analyzing and comparing the value of the references to EPEI with higher frequency of production (A's) between 2004 and 2008, it decreased significantly from 1,6 to 1,07 approaching the ideal value for these references (EPEI = 1).

Weekly diary levelling fulfillment was changed to a value very close to the ideal value, i.e. 100%. The weekly levelling fulfillment in 2004 was not evaluated because the production levelling in the company was not implemented. In 2008, the objective of this indicator was to 90%, very close to the ideal value (100%).

Comparing the number of days of stock of the final product between the period considered there is a decrease of two days, which shows that the project of pull levelling, in a first step already reduces the number of days of stock, but is expected later that this value could be further reduced. For the company, reduction of the stock for two days means a saving of capital tied up around 18 000 €.

Comparing the indicator LIWAKS, between 2004 and 2008, there was a substantial increase from 88% to 97%, approaching more the objective value: 100%.

#### **4. CONCLUDING REMARKS**

The objectives proposed for implementing the project of pull production levelling had been achieved. All actions planned for this implementation have been achieved: the tools necessary to pull the management of the supermarket of finished product in the local warehouse were developed; the physical implementation of the necessary mechanisms was created, the support and training to employees were given.

The implementation of this project considered three levels of planning: the weekly production of car radios, the weekly update of the level of stock and the level standard and daily monitoring of the circuits of Kanbans and the stock of finished product in the two circuits for OEM clients.

This project was evaluated and monitored through the indicators: Every Part Every Interval (EPEI), fulfillment of the plan of levelling Production Planning, the stocks level and the LIWAKS. All indicators were improved. These improvements were due to this project implementation that enabled the stability of processes meeting the prerequisite, i.e., fully satisfied the production levelling.

The final step was to implement this procedure to others final assembly lines but it was not a task for the author of this paper. The implementation of the pull levelling production was an important contribution to the global project of the organization where this work was developed.

## REFERENCES

- Cardoso, A., Arezes, P., Alves, A. and Carmo-Silva, S. (2008) "Reconfiguração de Sistemas de Produção Orientados ao Produto: Estudo de um Caso Industrial," Proceedings of 5º Congresso Luso-Moçambicano de Engenharia (CLME2008), 2-4 de Setembro, Maputo, Moçambique
- Costa, P., Alves, A. and Sousa, R. (2008) "Implementação da metodologia Quick ChangeOver numa linha de montagem final de auto-rádios: para além da técnica SMED" Proceedings of 5º Congresso Luso-Moçambicano de Engenharia (CLME2008), 2-4 de Setembro, Maputo, Moçambique
- Dick, Bob (1999) "What is action research?" Available on line at <http://www.scu.edu.au/schools/gem/ar/whatisar.htm> (accessed on 11 December)
- Gilmore, T., Krantz, J. and Ramirez, R. (1986) "Action Based Modes of Inquiry and the Host-Researcher Relationship," Consultation 5.3, 161.
- Liker, J.K. (2004) "The Toyota Way: 14 Management Principles from The World's Greatest Manufacturer", Edição McGraw – Hill, New York
- Macedo, P., Zacarias, M. S., Tribolet, J. (2004) "Técnicas e Métodos de Investigação em Engenharia Organizacional: Projecto de Investigação em Modelação de Processos de Produção." 5º Conferência da Associação Portuguesa de Sistemas de Informação.
- Monden, Yasuhiro (1983) "Toyota Production System", Institute of Industrial Engineers
- O'Brien, R. (2001) "Um exame da abordagem metodológica da pesquisa ação [An Overview of the Methodological Approach of Action Research]" In Roberto Richardson (Ed.), Teoria e Prática da Pesquisa Ação [Theory and Practice of Action Research]. João Pessoa, Brazil: Universidade Federal da Paraíba. (2001). (English version) Available: <http://www.web.ca/~robrien/papers/arfinal.html> (accessed 24-10-2008)
- Oliveira, Ana Raquel and Alves, Anabela C. (2009) "Operating modes in manufacturing cells – An Action Research study" in Proceedings of the 5th International Conference on Intelligent Manufacturing & Logistics Systems and Symposium on Group Technology and Cellular Manufacturing (GT/CM 2009), (Eds.) Mitsuo Gen, Gursel A. Suer, Hark Hwang, Kap Hwan Kim, Katsuhisa Ohno and Shigeru Fujimara – February 16-18, Kitakyushu, Japan, pp. 107-115
- Rapoport, R. N. (1970) "Three Dilemmas in Action Research" 23(4), 499-513.
- Susman, G. I. (1983) "Action Research: A Sociotechnical Systems Perspective," ed. G. Morgan, London: Sage Publications, 102
- Womack, J. P. and Jones, D. T. (1996) "Lean Thinking", Siman & Schuster, New York, USA
- Womack, J. P., Jones, D. T. and Roos, D. (1990) "The machine that changes the world", Rawson Associates, NY