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Using Lean Thinking Principles To Reduce Wastes In Reconfiguration Of Car Radio Final Assembly Lines

M. S. Oliveira[a,*], H. D. A. Moreira[a], A. C. Alves[b], L. P. Ferreira[c]

[a]*Department of Production & Systems, School of Engineering, University of Minho, Campus of Azurém, 4800-058 Guimarães – Portugal*
[b]*ALGORITMI R&D Center, Department of Production & Systems,School of Engineering, University of Minho, Campus of Azurém, 4800-058 Guimarães - Portugal*
[c]*ISEP – School of Engineering, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 431, Porto 4200-072, Portugal*

Abstract

Assembly lines are production systems designed to be oriented to the product and well known to be highly productive. Nevertheless, during this time-frame the product volumes could decrease and the assembly lines, previously very productive and efficient, becomes unproductive and inefficient. This happens in the car electronics components company where this study took place that due to customer´s demand decrease, produced volumes also decreased and provoked the appearance of wastes related with too much occupied space, unbalanced workstations, more capacity than needed, outdated standard work sheets, bottlenecks, to conclude, too many non-added value activities. This paper presents a reconfiguration proposal for two final assembly lines with the goal of adapt physically the lines to the actual production volumes and eliminate the existing wastes. The proposed reconfiguration translates into very positive gains for the company, namely, the release of 22% of the space occupied by the production lines, a reduction in the number of operators, a 50% increase in productivity for each of the lines and an increase in the utilization rate (23% for line 1 and 13% for line 2). In total, the monetary gains associated with these improvements were, approximately, of 125,600 m.u. per year.

Keywords: Lean Thinking; reconfiguration; car radio final assembly lines.

* *Corresponding author. Tel.: + 351 253 510 170; fax: + 351 253 510 139.*
E-mail address: miriamoliveira13@hotmail.com

1. Introduction

The phenomenon of globalization and the consequent dilution of trade borders has led to increased competition between companies. Faced with the global competitive pressure of an ever-changing market, companies are increasingly faced with requirements regarding flexibility, diversity, complexity of logistics, transparency and short

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delivery times [1]. Therefore, there is an increasing need to implement efficient and flexible production systems aimed at reducing production costs and allowing the customer to obtain the product with the shortest possible lead time, higher quality and lower cost [2]. It is in this context that Lean Production emerges whose goal is the elimination of waste and the creation of value [3]. The Lean philosophy focuses on the process of eliminating waste from the application of a series of tools, resulting in greater efficiency, effectiveness and profitability. The company where this project was held was also intended to eliminate waste by applying Lean Production. The focus of the project was in two auto radios final assembly lines characterized by being the oldest and the longest of the factory, occupying a total area of about 259 m^2. The objective of this project was to improve the utilization of the resources of these lines by eliminating the wastes identified in order to improve the use of space and increase productivity.

This paper is structured in six sections. The first one introduces the project and its objectives. The second presents the research methodology used to develop the project. Section three presents a brief literature review to introduce important concepts about lean production and the tools used during the study. The description, analysis and proposals presentation for the assembly lines improvement are presented in section four. Section 5 provides the discussion and evaluation of the results obtained by the implementation of the improvements. Finally, the conclusions are outlined in section six.

2. Research methodology

Action-Research was the research methodology used to develop this project once the researcher was actively involved in the company's activities. Action-Research can be characterized as a methodology that encompasses both action/change and research/understanding, based on a cyclical process where there is critical action and reflection so that, in later phases, methods, data and interpretation are perfected based on the experience/knowledge obtained in the previous phase [4]. According to O'Brien (1998) this methodology is organized in five stages: Diagnosing, Action Planning, Taking Action, Evaluating and Specifying Learning [5]. In the first phase of the methodology (Diagnosing), the goal was to identify the objects of study and plan the collection and analysis of the current status data. In the Action Planning phase, the improvement actions to be implemented were considered in order to solve the problems identified in the previous stage. In the development and implementation phase of improvement proposals, the actions planned in the previous phase were carried out. After implemented the improvement actions, the results were measured through the use of the performance indicators that were considered adequate to evaluate the impact of the changes made in the production system. The last phase consisted in the learning specification, where the suggestion of future work was made taking into account the analysis carried out and taking into account the point of view of the continuous improvement of the company.

3. Brief literature review

The term "Lean Production" first appeared in 1988 in John F. Krafcik's "Triumph of the Lean Production System" paper, however, it only became popular after the release of the book "The Machine that Changed the World" by Womack et al. (1990). The publication of these texts presented the world with the production system that revolutionized the performance of Japanese car companies, placing them in a prominent position when compared to Western companies. The Toyota Production System (TPS) was the production system created by Toyota that led Japanese companies to great efficiencies and gave rise to the famous concept "Lean Thinking" [6]. According to Womack and Jones (1996), the designation "Lean" is justified by the fact that TPS promotes the "doing more with less" philosophy, that is, to produce using less everything: less human effort, less equipment, less time and less space. Briefly, Lean's goal is to provide customers with exactly what they want using the least amount of resources possible. This type of approach leads the Lean to focus on reducing or, if possible, eliminating waste in order to improve productivity and product quality, significantly reducing costs **[3, 6–8]**. According to Taiichi Ohno and Shigeo Shingo the seven major types of wastes in a production system are: overproduction, over-processing, transports, motions, waits, defects and inventory. Womack & Jones (1996) defined five key principles considered fundamental to eliminate these wastes and to create value in products and processes: 1) value; 2) value stream; 3) flow; 4) pull system, and 5) pursuit perfection. Lean production uses multiple tools to help in the application of this principals. Some of the tools that were important for this project were visual management [9, **10]**, 5S methodology**,** poka-yoke mechanisms [10], standard work **[8, 12]** and kaizen [12]. Another important concept for this study was the concept of production line. This concept was first introduced by Henry Ford during the 1990s in the context of mass-production of automobiles.

These are characterized by their sequential work structure that leads to a high efficiency in the production of large quantities of articles and small variety [13]. Production lines can be classified according to the variety and sequence of articles they produce, thus dividing them into three categories: 1) mixed models line, 2) multi-model line, and 3) unique model line. According to Becker & Scholl (2006), the balancing of production lines is considered a fundamental problem that must be analysed when reconfiguring a production line. The problem of balancing consists of distributing the necessary workload in a balanced way by the workstations in order to use as few work stations as possible, avoiding the existence of bottlenecks and increasing the rate of production [14]. When it comes to reconfiguring a production line, it is fundamental to know the takt time and the respective cycle time of each model so that it is possible to correctly distribute the workstations and the workload of each one of them. Takt time represents the pace at which the market asks for a product unit, i.e. how long it takes to produce a unit so that output is aligned with the market [15]. Taiichi Ohno defines it as the result of the ratio between the planned operative time per day and the demand per day [8]. Similar to takt time (TT), cycle time (CT) defines the time required to complete the cycle of an operation [16]. In a production line, the cycle time of the line corresponds to the time of the most expensive workstation, thus representing the bottleneck of the line. It is important that the cycle time is as close as possible to takt time without ever exceeding it so that it is possible to produce the quantity of product required by the customer [16].

4. Description, analysis, and proposals presentation

The company where this project was developed is a multinational that produces electronic components for the automotive industry. The project was developed in an industrial plant where the production is mostly dedicated to car radios. The focus of the research was on two car radio final assembly lines.

4.1 Description of the productive process

The final assembly lines under study were characterized by being the oldest and the longest of the factory, occupying a total area of about 259 m^2. The production volumes corresponding to these assembly lines represented around 20% of the total daily volume of auto radios. In these lines were produced ten different models of auto radios where three corresponded to line 1 and seven to line 2. The process started with the manual assembly of components like brackets, *trimplates* (frontal part of the auto radio that is visible in the cars), CD player mechanisms, assembled PCB (printed circuit boards), among others, that come from different sections of the factory. Both lines had six workstations to manually assembly the components to assembly the final product, the auto radio (Figure 1).

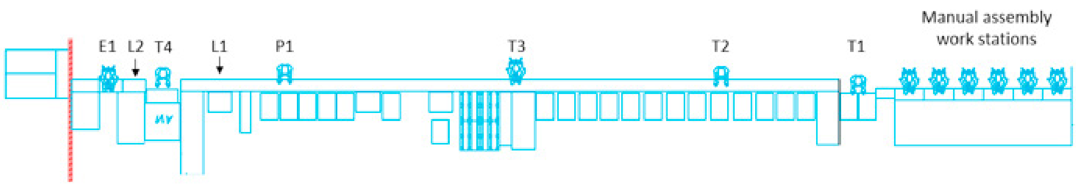

Fig. 1. Layout of a final assembly line.

After assembly process, the testing phase is followed to check the conformity of the products. Both lines, 1 and 2, have the same sequence of tests, however they vary in terms of the number of machines allocated. These tests are called "Tests Like Costumer" and are intended to simulate the use of the end customer in order to ensure the conformity of the device. The first station is the Illumination test (T1) whose function is to check the brightness of the buttons and the display. The second station is called the Electric Objective (T2) and its purpose is to test the electrical functions of the auto radio. The next test corresponds to the Electric Subjective (T3) where the operator interacts with the machine during the test in order to test the electrical and mechanical functions of the buttons as well as the quality of the display. The fourth station is called Programming (P1) where the auto radio is programmed with the content that is destined to it taking into account the brand and the model. The next station corresponds to the Labelling (L1). As the name implies, in this position the customer's label is placed on the product. Each label contains information on the make, model, serial number, place of manufacture and destination. The next post corresponds to Automated Vision

Inspection (AVI) (T4) where the visual inspection of the device is performed through an equipment that evaluates if the auto radio is visually compliant. Subsequently, there is the Passport (L2) station. The passport corresponds to a booklet with the access code and extra information about the auto radio. In this station the operator is responsible to print and fix the passport on the radio. The next station is the Mechanical Subjective (T5) where the operator verifies the device in terms of mechanics and aesthetics. The last station of the line corresponds to the Packing (E1). At this station, the operator packages the product according to the specifications of the make and model of the auto radio. After the packaging process the products are placed on pallets to be dispatched.

4.2 Problems identification and proposals presentation

This section presents the problems identification and proposals presentation for each identified problem. Three main problems were identified that resulted from many wastes in the current assembly line status. To identify such wastes, an analysis was developed: i) Pareto analysis to identify the most important models assembled in the lines; ii) process analysis diagrams analysis and time study; iii) balancing analysis; iv) bottlenecks analysis; v) Pareto defects analysis and vi) Non-value added analysis.

4.2.1 Bottlenecks and their removal

A bottleneck corresponding to the mechanical subjective station (T5) of the high runner of line 2 was identified that was generating wastes related to stocks, movements and defects. The accumulation of product generated by the bottleneck led to the need to accumulate stock of auto radios in boxes whose accommodation and handling increased the probability of occurrence of damage in the *trimplate* of the auto radio. To remove the bottleneck from the T5 station, it was necessary to evaluate alternatives to decrease the work content of this station. The solution went through the removal of the inspection to the click of the keys of the model B1 since this verification was already, in a certain way, performed in the position of subjective electric (T3). Thus, with the removal of this check, it would be possible to obtain a satisfactory CT and get a reduction of, approximately, 5 seconds (s).

4.2.2 Existence of non-value added activities and their elimination by a new passport design

In the L2 station of line 2, corresponding to the placement of the passport, the operator is responsible for printing it, folding it in half, inserting it inside a protective plastic bag and fixing it on the upper lid of the auto radio. In Figure 2 the operations performed on this workstation are shown sequentially.

Fig. 2. Sequence of operations from Passport station.

All the represented operations do not add any value to the product, and therefore creating a simpler design for this passport could significantly reduce the cycle time of this work station. The operator associated with this station is also dedicated to the AVI machine, giving a cycle time of approximately 22 seconds, in which 15,6 seconds correspond to the placement of the passport and 6,4 seconds correspond to the load and unload of the product in the machine. In order to reduce this sequence of operations, it was introduced the idea of changing the passport design. The new design would consist of a label that on one side would have the logos of the models and the other on the passport codes. This would have glue on the left side so that it was possible to open the label to be able to see both sides of it (Figure 3).

Fig. 3. New design proposal for the passport.

With this new design, the operator would only spend 5 seconds to fix the label on the car radio. This allowed a reduction of 12 seconds in the cycle time of this work station.

4.2.3 Over capacity and new balancing with a redistribution of operators

During the observation phase on the lines, it was noticed that they were completely stopped during most part of the second shift. Based on the production volumes, calculations of the productive capacity of both final assembly lines were carried out to be perceptible the difference between the capacity needed to produce and the one actually being used.

Table 1. Capacity analysis of Line 1 and 2.

	Capacity installed [s/day]	Available capacity [s/day]	Effective capacity [s/day]	Performed capacity [s/day]	Capacity needed [s/day]	Utilization rate
Line 1	86 400	57 600	55 440	54 387	40 811	75,00%
Line 2	86 400	57 600	55 440	53 943	45 480	84,30%
Total	172 800	115 200	110 880	108 330	86 291	77,80%

Through the data in the Table 1 it is possible to observe that the required capacity is much lower than the effective capacity, being used approximately 7 hours more than would be effectively necessary to fulfill the daily demand of these lines. To address this situation, capacity adjustment measures were taken to increase productivity and optimize the utilization of production resources.

The first step was to calculate the number of parts that would be effectively needed for the manual assembly of the components in each of the lines taking into account takt time information and the total processing time of each model that was obtained through the time study performed. Considering an efficiency of 96%, which corresponds to the standard value considered for the final assembly section, the number of parts was calculated by the ratio between the processing time and the takt time multiplied by the efficiency. From the calculations it was concluded that for both lines 1 and 2, it would take four workstations (WS) to carry out the manual assembly of the components to ensure that the production objectives are met in the future, avoiding that the cycle time exceed takt time.

The second step was to rebalance both assembly work stations from 6 to only 4. For that, Work Combination Tables (WCT) were created for each of the models produced. This tool consists of an Excel file where the tasks of each workstation and the respective motions are placed. The file automatically converts the motions in seconds and simultaneously builds a diagram that allows you to easily and quickly visualize the difference between the processing times of each task.

The third step was to rebalance the test stations in such a way that the cycle time of these stations was as close as possible to the cycle time resulting from the manual assembly balancing. For that it was necessary to calculate the number of machines required to balance each test station according to the cycle time of the assembly stations.

The calculation of the number of test machines required was performed based on the total test time of each machine and the manual assembly cycle time for each of the corresponding line models. Thus, from the calculation of the ratio between the processing time of each machine and the cycle time of the manual assembly it is possible to obtain the number of test machines required to meet the desired cycle time. Calculating the number of test machines required to meet the desired cycle time, there was a need to allocate the operators and redistribute the work content of the test stations for each of these (Figure 4).

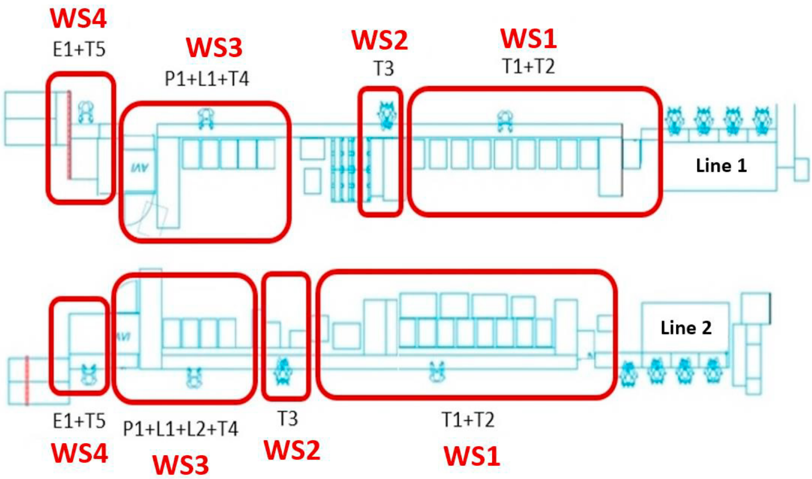

Fig. 4. New operators' distribution for the test stations.

With the new distribution of the operators by the test machines, there is a need to redistribute the workload so that the cycle time of the test machines is aligned with the operators' workload so that the operator does not have long waiting times. For this, WCT's were elaborated for each model of each line with the cycle time of each type of machine and the current distribution of the work by the operators in such a way that it was possible to redistribute the tasks according to the new cycle time proposed. Figure 5 shows the graphs of cycle times of machines and operators after balancing.

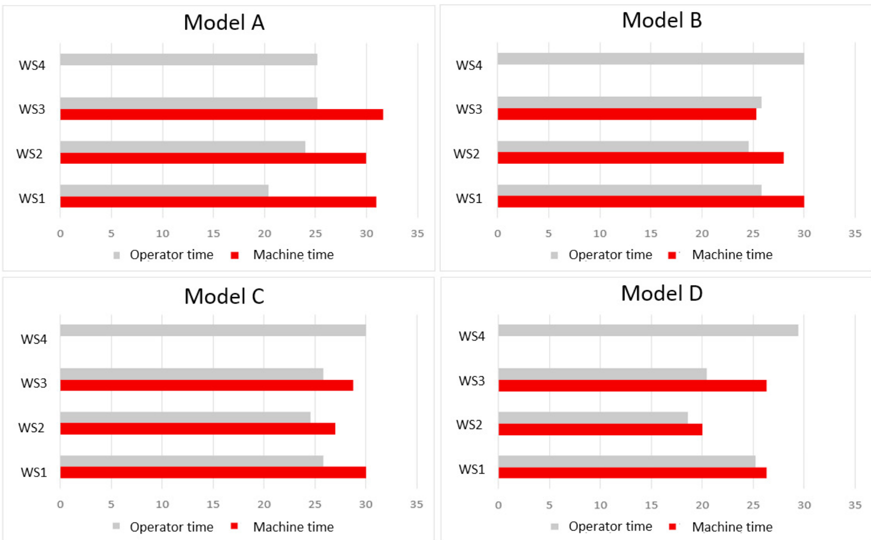

Fig. 5. Machine Time vs Operator Time.

Once the balancing is done, there was the need to physically re-adjust the manual assembly stations of each of the lines to the new distribution of the tasks. These changes were mostly related to changes in devices, parts presentation, screwing programs among other technical needs.

5. Results analysis and discussion

Removing the bottleneck allowed, not only to reduce the cycle time of the work station by improving line balancing, but also allowed to reduce the scrap percentage of *trimplates* from 2,21% to only 0,62%. Changing the passport design lead to a reduction in the number of operations to be performed, thus decreasing 12 seconds in the cycle time of this workstation. One of the goals of the rebalancing of the two final assembly lines was to reduce the space occupied. With the shortening of these it would be possible to obtain a reduction of about 8 m in the length of each one, obtaining a reduction of 56 m^2 of the total space. Considering that the annual cost per m^2 is 100 m.u., it was obtained a saving of 5,600 m.u. per year. Another goal was to reduce the number of operators in each line. With the rebalancing it was possible to reduce 3 operators in line 1 and 5 operators in line 2 resulting in a saving of 120,000 m.u. per year. Key performance indicators that were considered critical to measuring system performance were productivity and the utilization rate of production resources (Figure 6).

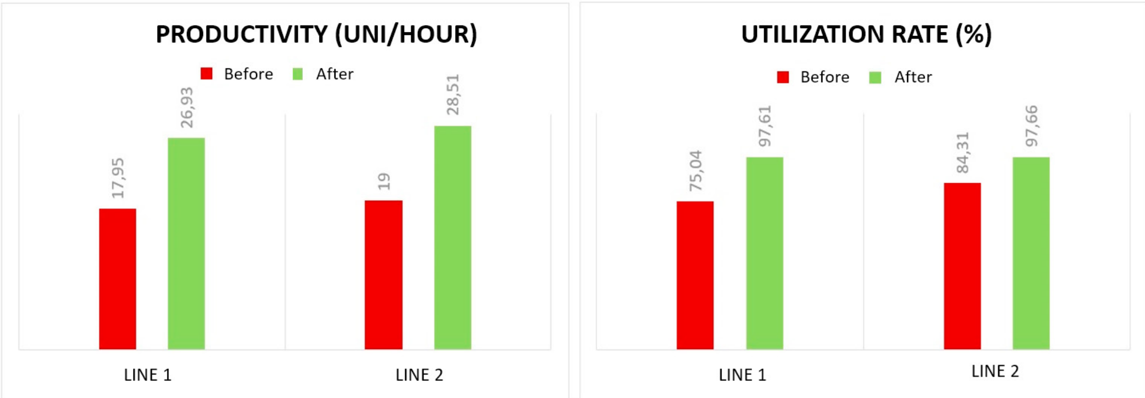

Fig. 6. Values of productivity and utilization rate before and after restructuring.

Productivity increased by, approximately, 9 units per hour for line 1 and 10 units per hour for line 2, which means that after the restructuration, the use of resources to produce what is required is much larger. This can be confirmed by the resource utilization rate since both lines would have a utilization rate of, approximately, 98%.

6. Conclusions

This project was part of the continuous improvement of a multinational company which is dedicated to the production of electronic components for automobiles. The main focus of the project was on improving the performance of two final assembly lines using Lean principles. The maladjustment of capacity of these lines led to the need for a reconfiguration that allowed to optimize the occupation of the space, the productivity and the rate of utilization. The proposed reconfiguration of the assembly lines translates into very positive gains for the company, namely, the release of 22% of the space occupied, a reduction of 38% in the number of operators, an increase in productivity of around 50% for each of the production lines (23% for line 1 and 13% for line 2). In total, the monetary gains associated with these improvements are in the order of 125,300 m.u per year. The company is aware that assembly lines must be reconfigured to maintain acceptable productivity levels acceptable and it must do this to all assembly lines. A company following Lean Thinking principles will have this continuous improvement mind-set.

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