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Improving the Machining Process of the Metalwork Industry by Upgrading Operative Sequences, Standard Manufacturing Times and Production Procedure Changes

Carlos Monteiro[a], Luís P. Ferreira[a], Nuno O. Fernandes[b], F. J. G. Silva[a,]*, Ivo Amaral[a]

[a] ISEP – School of Engineering, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 431, 4200-072 Porto, Portugal
[b]Escola Superior de Tecnologia, Instituto Politécnico de Castelo Branco, Castelo Branco, 6000-767, Portugal

Abstract

Manufacturing industries are currently experiencing important changes towards digitization and autonomous production control, which is known as Industry 4.0. However, the profitability of some companies, namely Small and Medium Enterprises (SMEs), and of some industrial sectors does not allow for great investments, meaning that is necessary to undertake simple changes that potentially can lead to significant gains. This is the case for the metalwork company under study, where wastes related to the large parts movement and non-conformities detected before and after the parts delivered to the customers have been identified. The elimination of these wastes can contribute to a significant increase in the profitability of the company. The use and integration of several Lean tools made it possible to achieve this goal for this company. Amongst other improvements on productivity and waste reducing, a 59% reduction in the time required to move parts of up to 1000 kg, a reduction of 2.04% on the external non-conformities (i.e. on non-conformities detected outside the company) and 3.99% on the internal non-conformities, was achieved.

Keywords: Machining, Metalwork, Intralogistics, Waste of time, Quality.

1. Introduction

The opening of markets, and the exponential development of computer and technological resources, as well as the training of all those involved in this context, have all ultimately been transformed into an issue of competitiveness for organizations. The need to perform better every day is inherent to the nature of companies, and

* Corresponding author. Tel.:+351 228340500; fax: +351 228321159.
E-mail address: fgs@isep.ipp.pt

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the increase of competition in the business world is staggering [1]. Within this scenario, there is thus a need to carry out the improvement and optimization of processes in a continuous and sustainable manner. According to Deighton [2], continuous improvement is imperative in any sustainable operation. Mo & Sinha [3] also claim that continuous improvement is the key to maintaining a sustainable engineering system, both in terms of reliability as well as continuous use. As such, the link between the supporting company and the engineering system itself must be strengthened. Kaizen is a Japanese word which means "Change for Better", and consists of the practice of continuous improvement. For Kiran [4], it is a Japanese philosophy or practice which concentrates on the continuous improvement of processes associated to manufacturing, engineering, services or any type of business management. Yet, while Kaizen can be defined as a mindset or philosophy, Lean should be seen as a method for the practical application of this philosophy by resorting to its own tools, such as: VSM (Value Stream Mapping) (5], 5S [6], PDCA (Plan-Do-Check-Act) [7], Heijunka, SMED (Single Minute Exchange of Die) [8], Poka-yoke, Kanban, Visual Management and TPM (Total Productive Maintenance) [9]. The work described in this article was developed at a metalwork company. Its main objective was to improve the production process of the Machining sector with the purpose of increasing productivity and reducing waste.

The remainder of this paper is structured as follows: section 2 reviews the literature; section 3 describes the methodology used to undertake the work at hand; section 4 provides an overview of all the practical work developed at the company, which includes proposals of continuous improvement for the process under study; section 5 presents all of the results achieved through the development of this work; and section 6 consists of the conclusions reached.

2. Review of literature

The ongoing effort to sustainably improve products, services or processes is designated as Continuous Improvement. This can be implemented by means of a wide spectrum of methodologies and tools. In a study which sought to understand the impact of the implementation of Lean principles and tools on the shipbuilding industry, it was concluded that VSM and standard work increased productivity by 45% in most of the companies involved [10]. Eduardo et al. [11] project sought the improvement of an equipment of the cork industry by introducing a variation, through the application of Lean methods. The SMED methodology was applied and a reduction of 43% in total changeover time was obtained. It was also created an A3 model to monitor the entire development of the SMED project, and the OEE (Overall Equipment Efficiency) calculation was implemented. Antoniolli et al. [12] refer that, in a study which addressed standard work, the adjustment and allocation of workstations led to the greater productivity and efficiency of two machines, increasing OEE (Overall Equipment Effectiveness) by 16%, from the previous 70% to 86%. Another study presented gains of 10% in the operator's availability time, through the use of tools such as the PDCA, 5S and 5W2H, at a company which manufactures cutting products [13]. Another study assessed the improvements achieved through the implementation of Kaizen methodology at a machining company. The results obtained – delivery performance, improvement in quality indexes; lead time; reduction of unnecessary movements; and overtime – indicated that the initiative to implement this methodology led to an enhanced, more extensive and more effective process of CI (Continuous Improvement) [14]. Another study was able to prove that 5S constitutes a tool of quality improvement which ensures constant performance. It was concluded that 5S promotes the participation of all the staff in the organization as a whole, thus enhancing teamwork, production, quality, flow, safety and maintenance. It was also made clear that 5S acts as the basis for the integration of other Lean tools, such as TPM and Kanban [15]. Another study presented a group of 41 Lean projects in the sector of industry, which took place over the course of a decade in northern Portugal, and which points to the importance of using Lean methodologies in companies. A list was drawn up of the implemented tools, and those which were used more frequently were identified. Amongst many other results, there was a 27% reduction in the time required for setup at a company producing cables for the automotive industry, which was achieved through the implementation of the JIT (Just-In-Time) system. In another sector belonging to the same company, a reduction of 40% was achieved for the same operation through the implementation of SMED and 5S. Another car radio manufacturer experienced a 30% increase in productivity by using standard work, as well as a 36% reduction of the WIP (Work In Progress) [16]. Arunagiri and Gnanavelbabu [17] identified the impact of Lean tools on the automotive sector by means of the weighted average method. Over 30 tools were used in a production environment, and the results revealed that five of the tools were those which generated the greatest impact when implemented, namely: 5S, OEE, 8 steps to problem solving, the Pareto chart and 7 types of waste. Finally, another different study [18] presented a case in which Lean principles were implemented at a company working for the automotive sector. The study pointed out that VSM is one of the main tools used to identify opportunities for improvement and to show the contrast before and after the

Lean measures were implemented. This method is also able to determine potential benefits, such as the reduction of lead time in production, and facilitates work dedicated to the inventory process. It was demonstrated that the implementation of VSM and its subsequent interventions, in this particular case, improved and reduced machining time by 14,17% and decreased manpower by 16,9%.

3. Methodology

In order to undertake this study, one adopted the Action-Research investigation method, the purpose of which is to transform the participating members into researchers through learn-by-doing practices [19]. This essentially consists of carrying out "an intervention of professional practice with the intention of enabling an improvement" [20]. This investigation method implies planning, acting, observing and reflecting more carefully on the everyday tasks executed in order to induce improvements in practices and ensure that participants have a better understanding of their practices [21]. For a comprehensive definition of Action Research, one must consider five phases [22]: Diagnosis: Identify or define the problem; Planning of actions: Consider different types of actions to address problems; Implementation of actions: Select types of action; Assessment: Study the consequences of actions; Specification of learning: Identify general discoveries.

4. Analysis and improvement of the machining process

This study essentially focuses on the area of Production in the company's Machining sector, from the entry of RM (Raw Material) to the exit of the FP (Finished Product). Thus, it is important to explain the context: firstly by presenting and explaining the work involved and, subsequently, the selection of products being analyzed, proposals for improvement and their implementation.

4.1. Mapping of the process and selection of products

The general process can be described as follows: once the order has been confirmed – see Figure 1 – it is placed by the sales department and followed by the completion of the IEN (Internal Execution Notice) so that the part can be cut. Production planning - PRP (Project Requirement Planning) - is subsequently carried out in relation to the cutting of the part, which is followed by the printing of the Order for Machine Production. After this phase, and depending on the workload, the pieces to be executed by subcontracts are analyzed and chosen. This selection process is undertaken manually and a decision is made as to whether the part will be executed internally. If this is not the case, a PO (Purchase Order) is issued, and the Machining production plan is carried out manually. The next phase, which is the most important of all, consists of the execution of Machining as such. After this stage, other parallel phases take place; these are related to other sectors and are irrelevant for the work at hand. It is also important to explain the sub-process of execution, which the study will essentially focus on. This process is the most susceptible to improvements and will generate greater gains in the short term. When the RM (Raw Material) enters the sector, the milling process is carried out on two faces by means of vertical milling machines. The milling of the four lateral sides is executed with horizontal milling machines. Chamfering is then carried out on all the edges so that the part does not present any sharp points. Depending on the customer's requirements, tapped holes are drilled so that eyebolts can be fitted to facilitate movement. These tapped holes are also designated internally as "eyebolts". Upon request, grinding of the workpiece is also possible. Finally, the FP (Finished Product) is cleaned and moved to its respective shipping station. An account of the materials which are produced in greater quantities must be carried out (figure 2); namely, one should identify the relations where improvements might generate better results. A correct process of accounting should consider the characteristics of the material, its length, width and thickness.

4.2. Problems identification

After analyzing and mapping the processes, one was able to identify and scrutinize the main problems in this sector: Parts with low machining cycle time; Undefined/incorrect operative sequences; Unsuitable theoretical manufacturing times; Considerable occurrence of internal/external Non-Conformities (NC).

4.2.1. Low machining cycle times

Setup times were found to be rather high for the milling operation. In addition, one was able to conclude that the allocation and daily management of work would have to be altered. The equipment and means used for moving material in the sector would also have to be improved.

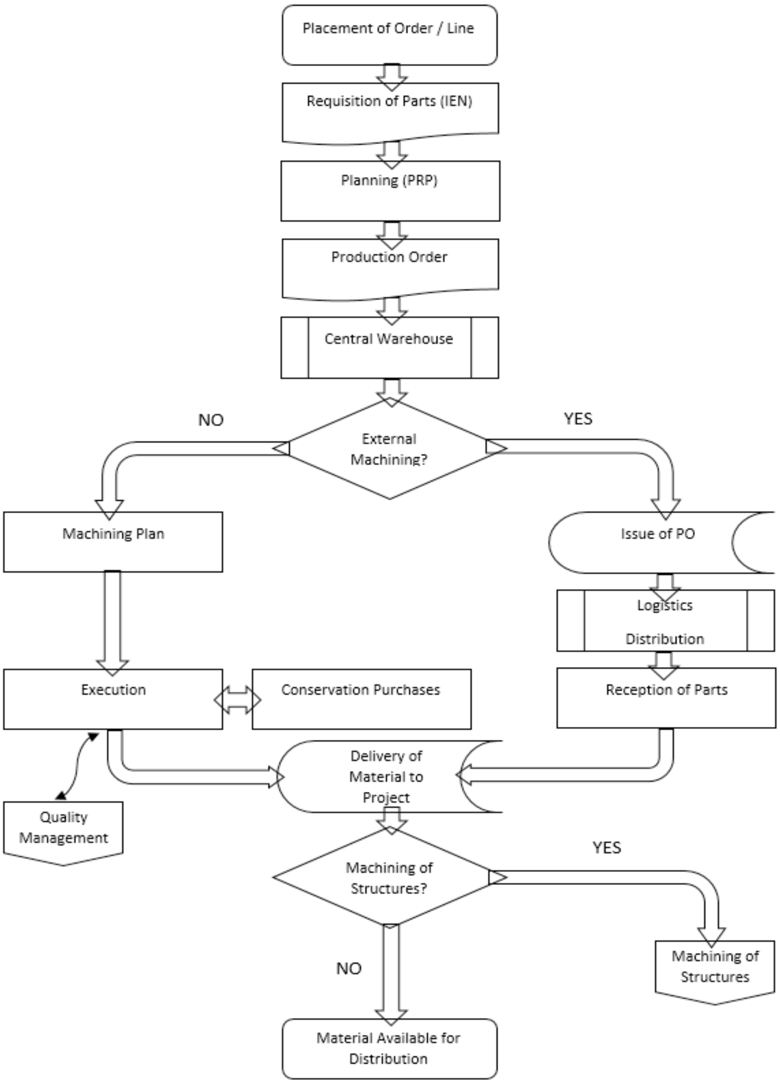


Fig. 1. Flowchart of the Machining Process.

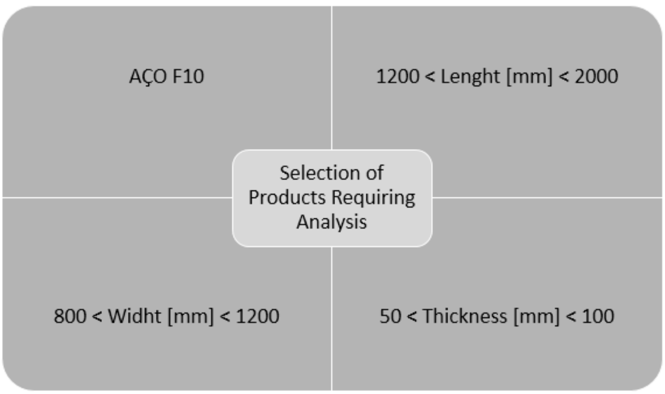


Fig. 2. Selection of products requiring analysis.

4.2.2. *Incorrect/Undefined operative sequences*

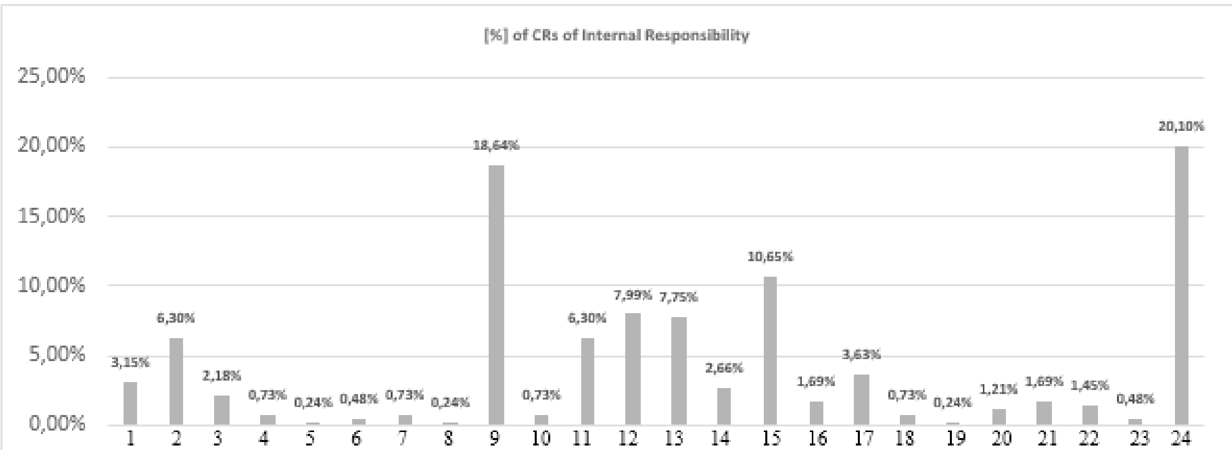
One was also able to verify that there were obvious shortcomings in the sequence of operations which appeared in the official production documents, designated as Production Orders (PO). The problems observed in this area consisted of: spelling errors in the operations designation; an outdated machine pool; incorrect designation of machinery; inadequate criteria for sizes and weights; incorrect sequencing of operations.

4.2.3. *Unsuitable theoretical manufacturing times*

Another of the problems detected was that the theoretical time for production did not match with real time and was thus inconsistent with the production time initially estimated. The main consequence of this problem resides in the discredit and lack of confidence expressed by collaborators regarding the information contained in the PO. As a result, the programming of Production is carried out empirically and is based on the experience of the staff responsible for this sector.

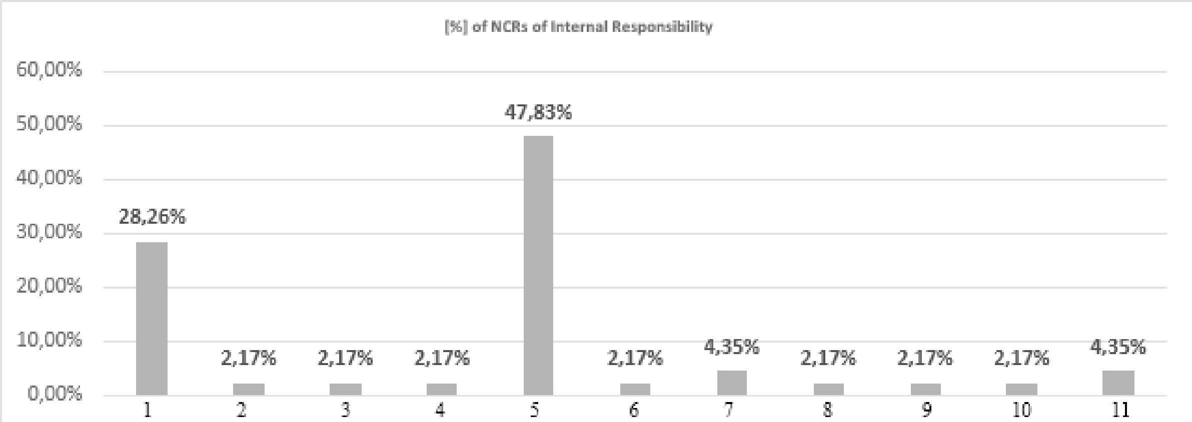
4.2.4. *Considerable occurrence of NC*

Quality constitutes a crucial factor in the success of companies and, as such, it must be analyzed and dissected in order to identify and correct defects (NC), as well as enhance CI at various levels. Listed below are the cases (quantity) of Non Quality (external detection-CR and internal detection-NCR only with internal responsibility), in accordance with figures 3 and 4, respectively). These were registered in the company's Quality System and broken down into the sector responsible for the defect, for the period between January and June 2017. It was thus determined that, according to the CR (Complaints Register: external NC), the Machining sector occupies the 5th position in the list of sectors which present the highest number of external complaints (6,3%) and is ranked 1st in the case of internal complaints (47,83%). This clearly indicates that the elimination of these defects is crucial. The company was also able to ascertain that these failures were mainly caused by Operator Error, both in the case of the CR as well as for the NCR (Non-Conformity Record: internal NC).



Legend: 1-Steel Warehouse; 2-Cell 2; 3-Cell 3; 4-Multipurpose Cell; 5-Cell 1; 6-Production M.; 7-Information Systems M.; 8-Technical and Quality M.; 9-Thermal Treatment M.; 10-Drawn Production; 11-Machining Production; 12-Cutting Tools; 13-Águeda Branch; 14-Braga Branch; 15-Lisbon Branch; 16-Marinha Grande Branch; 17-Porto Branch; 18-Management of Logistics and Planning; 19-Product Management; 20-Internal Logistics; 21-Structure Machining; 22-Oxycutting; 23-Product Reception; 24-Internal Sales Ovar

Fig. 3. CR 2017 Machining.



Legend: 1-Steel Warehouse; 2-Cell 2; 3-Thermal Treatment M.; 4-Drawn Production; 5-Machining Production; 6-Águeda Branch; 7-Internal Logistics; 8-Structure Machining; 9-Oxycutting; 10-Ramada Aços, S.A.; 11-Internal Sales Ovar

Fig. 4. NCR 2017 Machining.

4.3. Proposals for improvement

In order to improve and address the identified problems, one proposed the improvements presented in Table 1.

Table 1. Proposals for Improvement.

Process	Problems Identified	Solution
Machining	Low machining productive times	• Reduction of setup times by implementing the lean tool SMED • Alteration of work allocation and daily management of work • Improvement of means used to transport material
	Undefined/incorrect operative sequences	• Definition of new operative sequences
	Inadequate/unreliable theoretical production times	• Creation of new calculation formulae for production times • Update of machining parameters
	Occurrence of internal and external Non-Conformities	• Operators' training • An additional final check (double control)

4.3.1. Improvement of Production Times

Prior to the intervention, the allocation of work and schedules were carried out manually due to incorrect operative sequences and failures in the delivery of RM by the internal supplier SW (Steel Warehouse). In order to address these issues, the following changes were introduced:

- Organization of a daily inter-sector meeting called "5-Minute Lean", during which various sectors - Logistics, Steel Warehouse, Glitch Machining and Structure Machining – assess and identify priorities for that day and the following one;
- Previous analysis of requirements for the week (global) and day (specific): discussion of which parts will be executed according to identified priorities and advantages of processing (for instance, reduced setups);
- JIT supply for Machining based on planning instead of continuous and unlimited supply; consequently, the general RM reception area was eliminated and replaced with supply zones for each machine with a capacity for two pieces;

- The sector supervisor draws up a daily schedule for the parts to be executed on each machine;
- A new session was created on ERP (Enterprise Resource Planning), which will allow for the (computerized) display of the current state of parts, task by task. In this way, operators can conclude each task on time, thus facilitating the visualization of the workload (see the following point);
- Improvement of the production management system (software RamGest). Firstly, one proceeded with the alteration of the theoretical production times and operative sequence. In association with the development of the session described in the previous point, one was thus able to view the workload and delays, which allowed for a better management of the sector overall;
- Only team leaders are now responsible for the equipment used to move materials; this will ensure correct and timely supplies and a reduction in the time wasted by the unnecessary movement of materials (a global overview of the sector's priorities instead of the operator's perspective, which is singularly focused and lacks a wider vision of the work at hand).

As was previously referred, the procedure for work organization was altered, so that the heads of the sectors are now responsible for moving the gantries which deliver supplies to the machines. In addition, a 1000 kg column-mounted/jib crane was installed in order to provide greater autonomy of movement in the zone where one of the busiest machines is located. Two manual electromagnets (1T) were also acquired to move electromagnetic workpieces and parts.

4.3.2. Defined/Correct operative sequences

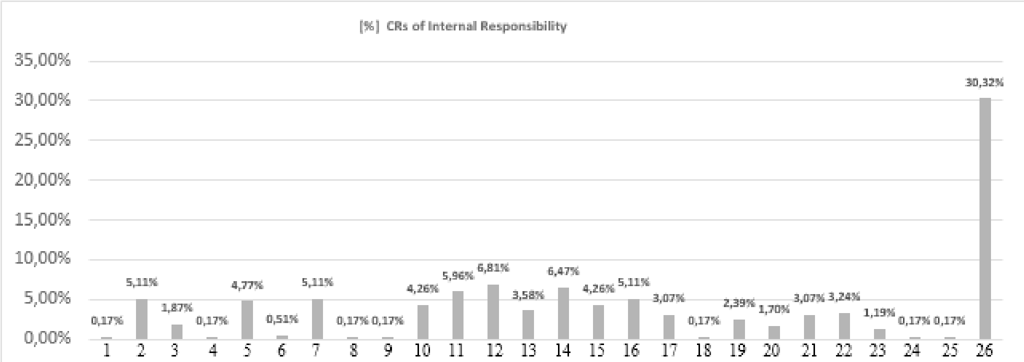
In line with the description of the detection of abnormalities, it was essential to correct: spelling errors in the designation of operations, the machine pool, the designation of machines, criteria based on sizes and weights and operation sequencing.

4.3.3. Adequate theoretical production times

Another of the factors which was important for the optimized operation of the sector is related to the adjustment of theoretical times for the different operations, namely Finishing, Roughing and Correction.

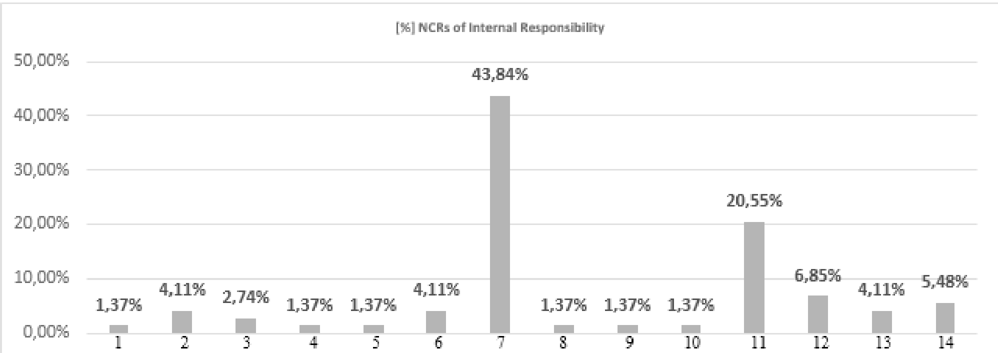
4.3.4. Considerable reduction in the occurrence of NC

Individual eight-hour training sessions were undertaken (for each operator); these deal with operations such as the setup procedure, the dimensional control of pieces using a pachymeter or micrometer, the visual control of pieces and analysis of the PO. In order to establish a comparison with the corresponding period and thus determine possible progress, one shall proceed with the presentation of cases of Non-Conformity (external detection-CR and internal detection-NCR only with internal responsibility) according to figures 5 and 6, respectively). These were registered in the company's Quality System and broken down into the sector responsible for the occurrences, between January and June 2018. One can observe that there was a considerable increase in NC at the company, more specifically 42,3% in the CR (external NC) and 58,7% in the NCR (internal NC). This might be explained by the fact that a sector dedicated solely to Customer Support was created and designated as such. Consequently, the treatment and follow-up of these processes was closely supervised and there were thus fewer errors. This means that all the smaller defects were also registered, leading to a significant increase in the reported cases. In relation to the Machining sector alone, a 3,85% decrease was registered in the CR section and an increase of 45,45% in the NCR section. An increase in sales was also recorded, which corresponds to an increase of 3,5%, when compared to 2017. In relation to the external processes (CR), as well as the internal ones (NCR), the company was able to ascertain that the main cause of defects was due to Glitch (the new classification for the older term Operator Error). It is also important to mention that, in percentage, the occurrence of NC cases in the Machining sector has decreased by 2,04% (CR) and 3,99% (NCR) from the time period January/June 2017 to 2018. Thus, despite slow progress, the implemented changes have caused some improvement. After determining that most of the failures which occurred were due to operator error, a new procedure was created with a new final task, a second control check, called double control.



Legend: 1-Steel Warehouse; 2-Cell 2; 3-Cell 3; 4-Marketing M.; 5-Information Systems M.; 6-Technical and Quality M.; 7-Thermal Treatment M.; 8-General Management; 9-Drawn Production; 10-Machining Production; 11-Cutting Tools; 12-Águeda Branch; 13-Braga Branch; 14-Lisbon Branch; 15-Marinha Grande Branch; 16-Porto Branch; 17-Management of Logistics and Planning; 18-Product Management; 19-Internal Logistics; 20-Structure Machining; 21-Oxycutting; 22-TT Production; 23-RamCutting; 24-Product Reception; 25-External Sales Ovar; 26-Internal Sales Ovar

Fig. 5. CR 2018 Machining.



Legend: 1-Steel Warehouse; 2-Cell 2; 3-Cell 3; 4-Information Systems M.; 5-Technical and Quality M.; 6-General Management; 7-Machining Production; 8-Cutting Tools; 9-Braga Branch; 10-Lisbon Branch & Porto Branch; 11-Internal Logistics; 12-Structure Machining; 13-RamCutting; 14-Internal Sales Ovar

Fig. 6. NCR 2018 Machining.

5. Results analysis

Table 2 presents a summary of the gains and improvements generated by the previously described solutions.

Table 2. Analysis of the results of the proposals implemented.

Opportunity for Improvement	Proposal/Solution	Qualitative Gains	Quantitative Gains
Low machining cycle time	Alteration of the allocation and daily management of work.	Improvement in communication, better coordination and organization, and better overview of the *WIP*.	It has still not been possible to quantify this parameter.
	Improvement of means used for movement.	Increase in autonomy.	-59% in the time required to move pieces of up to 1 ton.
Undefined/incorrect operative sequence	Definition of new operative sequences.	More standardized work procedures. Information of better quality and more reliability.	Parameter is not quantifiable.
Inadequate/unreliable theoretical production times	Creation of new formulae to calculate production times.	Improvement in the quality and validity of information.	Parameter is not quantifiable.
	Update of Machining parameters.		Parameter is not quantifiable.
Considerable occurrence of internal/external NC	Training of operators.	Collaborators possess greater technical propensity.	-2,04% in the Complaints Register; -3,99% in the Non Conformity Register.
	Additional final check (double control).	More confidence in the work undertaken.	

Considerable quantitative gains were achieved in the machining cycle time, namely: the time required to move pieces up to 1 ton. was reduced in 59%. Also, qualitative gains in the affectation and work management were registered. Correction of operating ranges and theoretical manufacturing times is not a quantifiable gain, but the quality of information, standardization and confidence of manufacturing data has been dramatically improved, with a visible increase in operator reliability and ease of production scheduling. Regarding the occurrence of NC, great improvements were not yet visible, the formation of operators is a parameter to be reinforced and executed continuously.

6. Conclusions

Manufacturing industry is currently undergoing considerable development towards digitization and automation (known as Industry 4.0). However, in the sector analyzed, profitability does not allow for great investments, and thus simple changes that generate great gains were carry out. This study demonstrates that by involving everyone, and even by focusing on processes which are very manual and of little investment, one can generate considerable improvements. It has also been proved that the use of one single Lean tool is not feasible; rather, it is essential to resort to several tools and their related concepts simultaneously, or either justify the use of one general tool and complementing it with various others during its implementation. Finally, the combination of all the tasks and work undertaken allowed for a 59% reduction in the time needed to move parts of up to 1 ton. In addition to the other qualitative improvements achieved, one was also able to reduce the occurrence of NC, more specifically 2,04% in the case of the CR and 3,99% in the NCR.

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