

Design and Implementation of a Quality Control System in an Elevator Industrial Company

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*Para o meu pai,
cujos olhos estarão certamente a brilhar neste momento.*

Abstract

The industry of elevators' manufacturing is becoming increasingly competitive, as in the current paradigm of mass customization, products with high variability, low time to market and the shortest possible production times are required. This competition comes not only from the competitors' pressure, but also from the high levels of quality demanded by customers. Therefore, a Quality Control System that allows the quality assurance of the final product, but which does not compromise the productivity of the company's shop floor and that ensures the elimination of as many non-value-added actions as possible is necessary. In this way, this work aimed the design and implementation of a Quality Control System in an elevator industry, in order to ensure the sustainability of the company.

For each of the company's stages of quality control (incoming, in-process and before expedition), standards and daily control plans were defined, with the objective of changing the quality control procedures from random/only based on the experience of the controllers to considering the history of deviations. For the incoming control, two new standards were implemented, integrated, which allowed the direction of controls for the most critical products/suppliers and which reduced the daily number of controls for products that never presented problems in the past, through the creation of a VBA programme. Similarly, for in-process control, the objective was to use the data stored in the company's ERP system in order to generate daily quality control plans. For this, the input data was taken from the ERP through an SQL routine, being later treated/processed through dynamic dashboards in *Power BI*. As a control method, work instructions were created, together with the implementation of a new tool for a real-time control registration: *iAuditor*. For the control before expedition, this tool was also used, being, however, this control very reduced, based on the TPS philosophy.

Through the implementation of this new Quality Control System, it was also possible to eliminate several *MUDAs*, as well as to suggest several improvements on the company's shop floor, such as the definition of new methods for reacting after the detection of deviations or the creation of mistake-proof systems (*Poka-Yoke*).

Keywords: Quality control; Data processing; Work standardization; *Poka-Yoke*; *MUDA*.

Resumo

A indústria da produção de elevadores está, atualmente, cada vez mais competitiva, na medida em que no atual paradigma de customização em massa são exigidos produtos finais com alta variabilidade, baixos tempos até chegada ao mercado e os menores tempos de produção possíveis. Esta concorrência advém não só da pressão dos concorrentes, mas também dos elevados níveis de qualidade exigidos pelos clientes. Assim sendo, é necessário um Sistema de Controlo da Qualidade que permita a garantia da qualidade do produto final, mas que não comprometa a produtividade do chão de fábrica da empresa, para além da garantia da eliminação do máximo de ações sem valor acrescentado. Desta forma, este trabalho teve como objetivo a estruturação e a implementação de um Sistema de Controlo da Qualidade numa indústria de elevadores, de forma a assegurar a sustentabilidade da empresa.

Para cada uma das etapas de controlo da qualidade da empresa (à entrada, em processo e à saída), *standards* e planos diários de controlo foram definidos, com o objetivo de fazer com que os processos de controlo da qualidade deixassem de ser aleatórios/apenas baseados na experiência dos controladores e passassem a ser realizados tendo em conta o histórico de desvios. Para o controlo à entrada, foram implementadas duas novas normas, integradas, que permitiram a direção dos controlos para os produtos/fornecedores mais críticos e que permitiram a diminuição do número diário de controlos a produtos que nunca apresentaram problemas no passado, através da criação de um programa VBA. Da mesma forma, para o controlo em processo, o objetivo foi usar os dados armazenados no sistema ERP da empresa de forma a gerar planos diários de controlo da qualidade. Para isso, esses dados de *input* foram retirados do ERP através de uma rotina SQL, sendo posteriormente tratados/processados através de *dashboards* dinâmicas em *Power BI*. Como método de controlo, foram criadas instruções de trabalho, bem como foi fornecida uma nova ferramenta para um registo de controlos em tempo real: *iAuditor*. Para o controlo à saída, também esta foi a ferramenta escolhida, sendo, no entanto, este controlo muito reduzido, tendo como base a filosofia TPS.

Através da implementação deste novo Sistema de Controlo da Qualidade, foi também possível a eliminação de diversos *MUDA*, bem como a sugestão de várias melhorias no chão de fábrica da empresa, tais como a definição de novos métodos para a reação após deteção de componentes não conformes ou a criação de sistemas à prova de erro (*Poka-Yoke*).

Palavras-chave: Controlo da qualidade; Processamento de dados; Standardização de trabalho; *Poka-Yoke*; *MUDA*.

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Abbreviations

Ac – Acceptance Number

AQL – Acceptable Quality Level

BI – Business Intelligence

BOM – Bill of Materials

C2 – Purchasing Department

ERP – Enterprise Resource Planning

IoT – Internet of Things

IT – Work Instruction

KPI – Key Performance Indicator

MAG – Metal Active Gas

NI – Normal Inspection

NCF – Non-conformity that is only detected outside the shop floor

O1 – Planning Department

P10 – Mechanical Transformation Section

P20 – Welding Section

P30 – Electrostatic Painting Section

P41 – Doors Assembly Section

P42 – Electrical Assembly Section

P43 – Shaft Equipment Assembly Section

P50 – Logistics Department

P60/PEP – Production Planning Department

PAUT – Phased Array Ultrasonic Testing

PDCA – Plan, Do, Check, Act

Pn – Non-conformity that is detected within the shop floor

QMB – Quality, Environment and Security department

RFID – Radio Frequency Identification

RI – Reduced Inspection

S1+ – *Schmitt 1*

S2+ – *Schmitt 2*

SKU – Stock Keeping Unit

SL – Skip-Lot Inspection

SQL – Structured Query Language

TI – Tightened Inspection

TPS – Toyota Production System

VBA – Visual Basic for Applications

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1 Introduction

This report was carried out as part of the dissertation project of the 2nd year of the Master's Degree in Mechanical Engineering. The study was developed in the company *Schmitt Elevadores*, together with the Process Engineering department and the theme focuses on the management and organisation of the company's quality teams and processes.

1.1 Schmitt Elevadores

The Portuguese company *Schmitt Elevadores* was incorporated in 1963, as part of the multinational company *Schmitt + Sohn*, founded in 1861, in Nuremberg, Germany. Currently, the group has production centres in Kornburg, Germany and in Porto, Portugal, that are dedicated to the design, production and assembly of elevators. Besides this, the company has multiple delegations in Germany, Portugal, Austria and Czech Republic, that are devoted to sales, on-site assembly and after-sales services, such as maintenance and modernizations. In Portugal, the delegations are spread along the country in the cities of Braga, Porto, Coimbra, Lisboa, Castelo Branco and Faro.

In Porto, Portugal, the production plant of *Schmitt Elevadores* is divided into two main units: *Schmitt 1* - the headquarters of the company - in which are placed the administrative and project services, the electrical assembly and the main warehouses of the company (divided by mechanical, electrical and after-sales components); and *Schmitt 2*, fully devoted to manufacture, in which is placed the mechanical production and mechanical assembly of the elevators. Currently, the production rate of the factory is around 1200 elevators per year. Each elevator is constituted by around 20000 components.

1.2 Motivation and objectives of the project

The project in which this dissertation is placed, named *Design and Implementation of a Quality Control System*, emerged from the necessity of increasing the efficiency of the quality control processes and to increase the quality levels of the company. Its main objective is the definition of the critical steps of the different stages of the industrial processes (incoming of products, in process and before dispatch of products) and the implementation of a Quality Control System based on those critical steps. This system must consist of a *toolbox* of methods and tools to apply in the quality control processes. For each method/tool, a variety of parameters must be defined (Table 1): who will do/use it, its periodicity, its inputs and also a small description/standardization of the method/tool.

In order to reach the main objective of the project, the following steps must be completed:

1. To monitor the process *AS IS*;
2. To study the parameters that might influence the products' quality. To analyse and to categorise non-conformities. Causes analysis;

3. To identify improvement opportunities;
4. To define quality control methods/tools *TO BE*.

It is important to state that the scope of the project consists in the production's shop floor and in the reception of parts at the warehouses. Any other department of the company is considered to be out of scope.

Table 1: Toolbox matrix scheme.

Control method/tool	Who?	Periodicity?	Input (trigger)	Description/Standardization
...	...	...	...	...
...	...	...	...	...
...	...	...	...	...

1.3 Methodology of the project

The project's methodology was based on a *Lean* tool, the A3 report, that was used for the presentation and the discussion, in weekly meetings, of the progress and developments made in the work. This tool is used for each project of *Schmitt Elevadores*, as it facilitates the application of the Plan-Do-Check-Act (PDCA) management, by dividing a problem into smaller parts, allowing its quicker analysis and further quicker and continuous solutions implementation (Kaizen's philosophy) (Bordin, et al. 2018) (Pereira, et al. 2019). The A3 report, as a communication tool, is presented in a DIN-A3 sheet and follows a logical, visual and standardized structure (Tortorella, Viana and Fettermann, 2015). While clearly summarizing the collected information, it assures that everyone involved has a common vision of the project, that is, having the same perspective of the problem, leading to the alignment of ideas, interests and opportunities (Vieira and Weiss, 2021).

By using this structure, it is possible to guarantee that the process is guiding the user, allowing to "make decisions slowly by consensus" – 13th principle of the Toyota model (Tortorella, Viana and Fettermann, 2015). The A3 report used in the company is divided into nine sections, presented in the following enumeration:

1. Definition of the problem: the main objective is presented and structural questions about the project are answered, based on the 5W2H tool – what will be done, why is it going to be done, where it will be implemented, who will do it, when it will be done, how it is going to be done and how much will it cost;
2. Current condition: definition of the current state of the company;
3. Target condition: quantifiable statement (KPIs) and definition of the target to be achieved;
4. Analysis of causes: application of the 5 whys method;
5. Solutions design: countermeasures to improve the current situation and achieve the determined goals of the project;
6. Solutions testing;
7. Plan of action: how and when will the countermeasures be put into practice?;
8. Obtained results: follow up plan;
9. Future actions and lessons learned: expansion of the work to other fields of the company.

Together with the A3 report, since the beginning of the work, two task schedules were constructed and have been updated so that there was a constant integration of time organisation with the objectives of the project itself. The first *Gantt* chart, presented in Figure 1, was created considering the dissertation tasks, while the second, presented in Figure 2, was constructed considering the tasks associated to the proper work in the company.

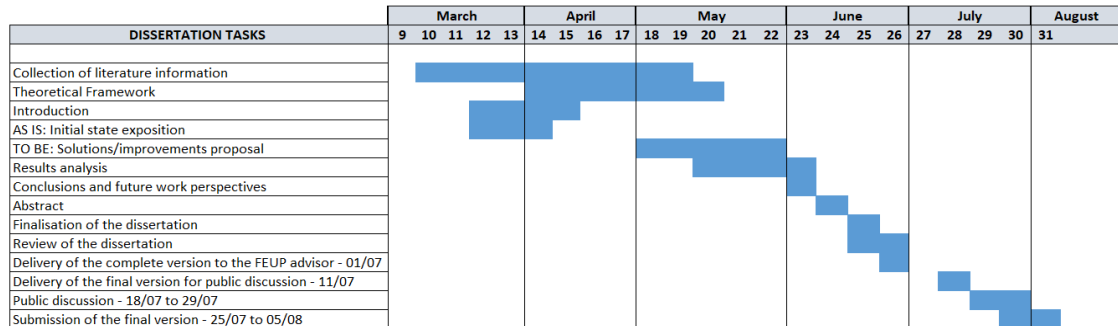


Figure 1: Gantt chart for the dissertation writing tasks.

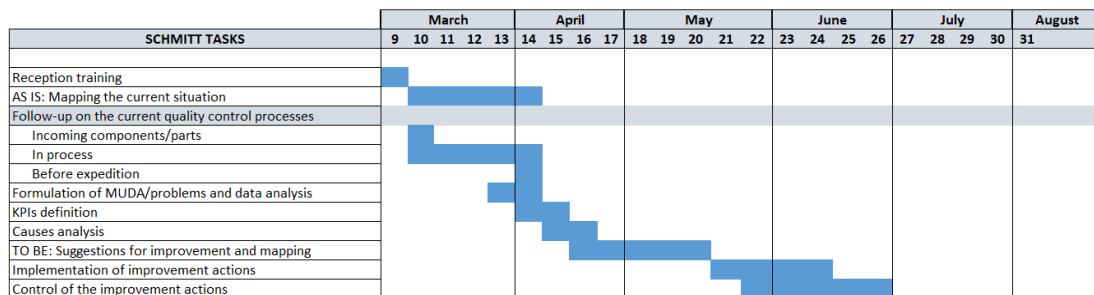


Figure 2: Gantt chart for the company tasks.

It is possible to state that both tools, the A3 report and the *Gantt* charts not only relate to each other, but also complement each other. The A3 report used for this project is presented in Appendix A.

1.4 Dissertation structure

This report is divided into five chapters.

In Chapter 1, a brief introduction to *Schmitt Elevadores* was made, as well as to the project associated with this dissertation: its motivation, objectives and methodology.

Chapter 2 presents a theoretical framework that serves as a basis for the mind-sets already adopted by the company, as well as for the solutions that are suggested in Chapter 4.

In Chapter 3, a brief description of the company's production process is presented, allowing for a description of the types of quality control that are currently carried out in each of the relevant sections. An analysis to the company's non-conformities is also conducted. In the end of the chapter, an enumeration of several problems of the current Quality Control System is presented, corresponding to the input for the next chapter.

Chapter 4 presents the various improvements that were proposed during the work. Regarding these proposals, the analysis of the results obtained from the solutions that were possible to implement is carried out. Regarding the ones that could not be implemented, the expected results are presented.

Chapter 5 defines the conclusions of this dissertation as well as perspectives for future work.

2 Theoretical framework

This chapter aims to serve as a review of the theoretical concepts and methodologies that will be used along this report. This is essential to present the different aspects covered throughout the project, as studies carried out by other authors support the veracity of this dissertation. Quality concepts and quality control methods are described. *Lean Manufacturing* and *Industry 4.0* tools and their application are also enhanced.

For the elaboration of this chapter, research was carried out mainly on scientific articles and books dedicated to the topics discussed, in order to deepen the concepts presented below.

2.1 Quality control

Montgomery (2009) firstly presents a general definition of quality as “...one or more desirable characteristics that a product or service should possess.”. Then, a traditional and customer oriented definition is also purposed, as it is based “...on the viewpoint that products and services must meet the requirements of those who use them.”, corresponding quality to the fitness for use. Finally, a modern definition is also presented, where quality is “...inversely proportional to variability.”. Thus, it is possible to state that if there is a quality deterioration of the output, the customer satisfaction levels will significantly decrease (Sunder and Antony, 2017).

In order to evaluate the quality of a product, an inspection or test might be made. To inspect or test a part/product means to follow a “...series of steps, involving checking dimensional measurements against tolerances or control limits, visually examining the smoothness of surfaces, or making a device perform some of its intended functions.”. The aim of quality controlling by inspections is considered to be the “...effectiveness and standalone efficiency” of those inspections: firstly, the inspection procedures are defined and then the objective is to perform them with the minimum amount of resources (Baudin, 2002).

According to Ortiz and Park (2011), quality control can be divided into two different tasks. The first one is to guarantee that the supplied products are within the engineering specifications: this task is commonly called as incoming inspection. These inspections are important as they “...preserve value and prevent the costly practice of waiting to discover a noncompliant item only after it has made its way into the value-adding processes.”. When comparing costs, it is possible to state that to find a non-conformity at the receipt of the product is far less expensive than to let it go through the processes, resulting in a defective component. The second task corresponds to the in-process verifications of the products.

Quality and non-quality costs

Quality costs might be used as a tool that assist the quantification of the quality levels of a company and, consequently, as a tool that might improve that company's productivity (Starčević, Mijoč and Mijoč, 2015).

Traditionally, when talking about quality costs, they were only associated to inspection and testing of finished products. All other quality related costs were considered to be overhead costs of global product manufacturing process: those might be referred to as part of the “hidden factory” concept, that “...refers to the use of facilities and resources for the purpose of repairs, re-testing, re-making and other remedial activities related to the poor quality of a product.” (Starčević, Mijoč and Mijoč, 2015).

However, there was a shift in the way of classifying these costs. Now, the global quality costs are divided into two main categories: the quality-costs and the non-quality costs (Figure 3). On the one hand, the quality costs cover the prevention and appraisal measures that are taken in terms of quality, having a positive impact to the company. On the other hand, the non-quality costs cover the internal and external associated to failure costs, having, thus, a negative impact. When a company incurs in higher non-quality costs than the quality ones, this might mean that this company is “...remedying the problem situations instead of preventing them.” (Starčević, Mijoč and Mijoč, 2015) (Ertel, Raupp and Borba, 2017).

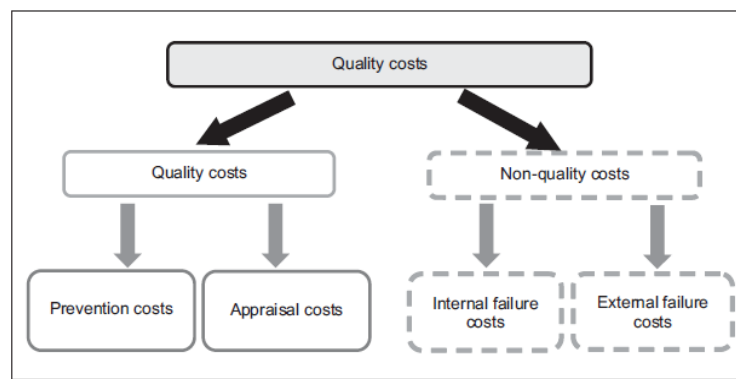


Figure 3: Types of quality costs within a company (Starčević, Mijoč and Mijoč, 2015).

2.2 Incoming quality control: acceptance sampling

One of the most used inspection procedure aiming the use of the minimum amount of resources is the application of sampling plans (Baudin, 2002).

Acceptance sampling is a quality assurance tool, defined in Montgomery (2009) as “...the inspection and classification of a sample of units selected at random from a larger batch or lot and the ultimate decision about disposition of the lot...”. The sampled lots might be accepted or rejected. It is stated that these inspections usually happen at two points: in the incoming of raw materials/components and after production. This quality control strategy is a solution to replace the other possible policies: the first one is the 100% inspection method, that although being able to guarantee that none non-compliant products go through the process flow, requires high quantities of money, time and resources; and the second one, no inspection, that as no inspection costs associated, but let no-compliant products go through the process flow. It is important to note that, when “... a sampling plan is adopted, some unsafe product may pass inspection.” (Montgomery, 2009) (Hlioui, Gharbi and Hajji, 2015).

Acceptance sampling plans might be divided into plans for attributes (“quality characteristics that are expressed on a go/no-go basis”) and plans for variables (“quality characteristics that are measured on a numerical scale”) (Montgomery, 2009). In this document, only attributes’ plans will be considered, as these are the ones needed for the development of the work within the company.

Standard attributes sampling plans were developed during World War II, as an “...outgrowth of statistical contributions to the war effort...”, being the most widely used the MIL STD 105E (1989). However, in 1995 this standard stopped being supported by the U.S.

Department of Defence, leaving, nevertheless, many derivative standards that are being used to this day (Neubauer and Luko, 2012). Nowadays, the best used standard in international trade is the ISO 2859-1 (1999), that defines *Sampling Schemes Indexed by Acceptance Quality Limit (AQL) for Lot by Lot Inspection*. This standard has “...undergone substantial modification...” from the military standard.

2.2.1. ISO 2859-1

The acceptance quality level (AQL) is the “...quality level that is the worst tolerable process average when a continuing series of lots is submitted for acceptance sampling.”.

ISO 2859-1 purposes three different inspection plans, for different AQL levels: normal, tightened and reduced. For each one of these, the sample size and the acceptance number are defined considering the size of the received lot. One lot is accepted if, within the inspected parts (sample), the number of non-conformities is equal or lower than the acceptance number (Ac).

When a new product is supplied, the adopted plan must be the normal inspection (NI), “...unless otherwise directed by the responsible authority.”. When in NI, the inspection plan might be changed to reduced or tightened inspection, as it is possible to observe in Figure 4 and as it is stated in the following points. Note that, in Figure 4, the presented requirements are only related to the number of accepted/rejected lots, other might be considered if the production rate is not steady or if stipulated by the responsible authority.

1. Normal to tightened: when a product is in NI and 2 out of 5 consecutive lots are rejected, the product enters in tightened inspection (TI);
2. Normal to reduced: when a product is in NI and the variable *Switching Score* reaches 30, the product enters in reduced inspection (RI).

The *Switching Score* is a variable used to calculate whether a product in NI might go to RI or not. It is calculated considering the acceptance number of each inspected lot.

When in TI or in RI, the inspection plan might be changed back to NI as follows:

1. Tightened to normal: when a product is in TI and 5 consecutive lots are accepted, the product enters in normal inspection (NI);
2. Reduced to normal: when a product is in RI and a lot is rejected, the product enters in normal inspection (NI).

It is also important to note that, when in TI, the inspection of a certain product might be discontinued, if 5 consecutive lots are rejected. The product might enter TI again if the supplier proves to take some action in terms of the quality of his product.

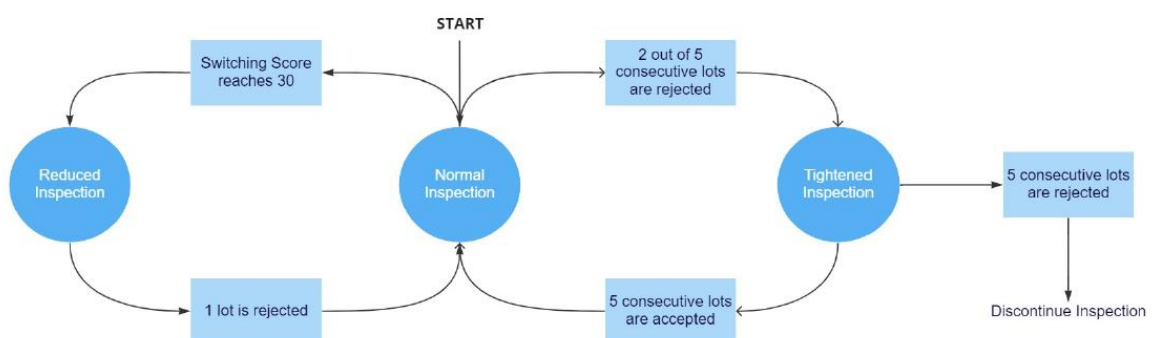


Figure 4: Inspection plans suggested by ISO 2859-1.

Considering the analysed inspection plans, a question may arise: does it make sense to inspect every single batch when there is a good-quality history? In these cases, a reduction in the number of inspections might be considered, through the implementation of *Skip-Lot Sampling Procedures*. In (Montgomery 2009) it is stated that these plans "...should be used only when the quality of the submitted product is good as demonstrated by the supplier's quality history.". This type of sampling is specified in ISO 2859-3 (1994).

2.2.2. ISO 2859-3

A *Skip-Lot* inspection is defined as an acceptance sampling procedure in which some batches of a series are accepted without inspection. Thus, there are some stringent requirements that a product must fulfil to be able to be inspected in a *Skip-Lot* methodology:

1. Considering the ISO 2859-1, the product should never have been, within its history, in a tightened inspection plan;
2. The previous 10 analysed consecutive batches must have been accepted;
3. The number of non-conformities within the previous 10 batches indicates the minimum number of products that must have been inspected; if this minimum number is not met, more batches must be inspected, until it is reached;
4. For the last two inspected batches, the acceptable number of non-conformities must be met.

When a product fulfils all these specified requirements, a frequency of batch inspection must be defined to start with. ISO 2859-3 defines three different possible frequencies to start the lot inspection:

1. 1 in 2 lots is inspected: used when more than 20 batches are needed to fulfil the 3rd requirement of *Skip-Lot* inspection;
2. 1 in 3 lots is inspected: when to fulfil de 3rd requirement of *Skip-Lot* inspection are needed 20 or less batches and one or more of them are not accepted in terms of maximum number of non-conformities;
3. 1 in 4 lots is inspected: when to fulfil de 3rd requirement of *Skip-Lot* inspection are needed 20 or less batches and all of them are accepted in terms of maximum number of non-conformities.

It is important to state that, for this inspection plan, the acceptance level of each individual lots is the same as the one used in the normal inspection plan of *Lot-by-Lot* sampling.

Throughout the inspection process of a *Skip-Lot* sampling plan, the frequency of inspection might be reduced to the following lower inspection frequency if the 3rd requirement of *Skip-Lot* is fulfilled. The *Skip-Lot* inspection of a product must be stopped when the last inspected batch surpasses the acceptable number of non-conformities and the product in question must be re-submitted to a *Lot-by-Lot* inspection.

2.2.3. Action after rejected product/part

Once the acceptance sampling control of the incoming products is completed, it is necessary to define what happens to the rejected lots. Hlioui, Gharbi and Hajji (2015) firstly present two general strategies with respect to this subject: on the one hand, it is possible to apply a 100% inspection policy (*100% policy*), in which the conforming parts are used and the non-conforming are dismissed or reworked; on the other hand, in the second strategy, the entire lot is returned to the supplier and a new order is made (*ret policy*). However, it is stated

that both strategies are not ideal. The first one, *100% policy*, despite assuring the presence of a better quality of the incoming raw materials, is also associated to high inspection costs, costs that may be totally unnecessary if there is a high level of stock of that component; the second one, *ret policy*, reduces the total costs of the inspection operations, but “...increases the lead time and results in an important finished product shortage risk.”, as the availability of the raw materials might be reduced, leading to possible production processes stoppage.

Thus, the stated authors purpose that the quality inspection decisions must be “...coordinated with production and replenishment activities to ensure better control at minimal costs.”, that is, “...should not be taken independently of the whole system.”. This is where the third strategy emerges, an hybrid combination of the two last strategies, the *hyb policy*. In this policy, the decision of returning or not the rejected lot is taken considering the finished product stock level ($y(t)$). A threshold, Z_2 , is defined and if the stock level is above this value, then it is considered that the system “...has enough finished products to reduce the risk of backlog...”, being advisable to return the rejected lot to the supplier. If, on the contrary, the stock level is below the Z_2 value, then a 100% inspection is selected, in order to “...ensure the continuity of the production process.” (Hlioui, Gharbi and Hajji, 2015).

In Figure 5, it is possible to observe a summary of the stated policies. It is important to note that they are defined for single sampling plans, in which n corresponds to the sample size, c to the acceptance number and d to the number of defective items found in the inspected sample (Hlioui, Gharbi and Hajji, 2015).

$$\begin{aligned}
 \text{100\% policy : } & \begin{cases} \text{Inspection limited to the sample } n, & \text{if } d \leq c \\ \text{Full inspection and rectification operation,} & \text{otherwise.} \end{cases} \\
 \text{Ret policy : } & \begin{cases} \text{Inspection limited to the sample } n, & \text{if } d \leq c \\ \text{Return of the lot,} & \text{otherwise.} \end{cases} \\
 \text{Hyb policy : } & \begin{cases} \text{Inspection limited to the sample } n, & \text{if } d \leq c. \\ \text{Otherwise, } & \begin{cases} \bullet \text{ Full inspection and rectification operation,} \\ \bullet \text{ Return of the lot,} & \text{otherwise.} \end{cases} \end{cases}
 \end{aligned}$$

Figure 5: Post rejected product/part policies (Hlioui, Gharbi and Hajji, 2015).

2.3 In process quality control

As previously stated, besides the quality control procedures to the incoming products, the quality control at the shop floor, during the manufacturing processes, has also high relevance to the general quality levels of one company. This happens because, frequently, these processes are repetitive and require high precision and, being carried out or monitored by humans, factors like distraction, fatigue, lack of training, within others, might arise (Alves, et al. 2021).

In this section, some of the standardized recommended quality control tests to specific parameters, according to the existing manufacturing processes of the company in study, will be presented.

2.3.1. Quality control after thermal cutting

Nowadays, despite the noted increase of the production's automation, the quality of the cutting edges after thermal cutting processes is still, usually, evaluated by humans. Thermal cutting processes are considered to be complex, as they depend on numerous

influencing factors that change within time, which translates into the need of regular checks (Tatzel and León, 2021).

The thermal cutting processes result in products with different qualities at the cutting edges, result of both chosen process and cutting parameters used. The different categories of quality are defined by ISO 9013 (2017), that purposes the evaluation of a cutting edge by two different parameters: the surface roughness and the cutting perpendicularity tolerance (u), defined as the difference between the lowest and the highest value of the cutting profile (Figure 6). Regarding the surface roughness, it is stated that high values will result in the existence of larger notches, leading to an earlier start of the crack initiation and in the decrease of the fatigue strength. Considering the cutting parameters, it is possible to state that the cutting velocity has an influence on the surface roughness value: by decreasing the velocity, the roughness will also decrease, leading to an increase in the product's quality. The same happens to the perpendicularity tolerance: this value decreases when the cutting velocity is decreased, leading, again, to an increase in the product's quality (Diekhoff, Hensel, et al. 2019) (Diekhoff, Drebing, et al. 2021).

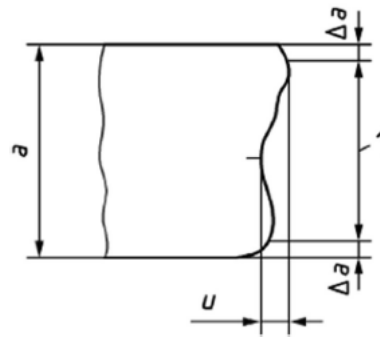


Figure 6: Perpendicularity in thermal cutting (Diekhoff, Drebing, et al. 2021).

2.3.2. Quality control after welding

Referring to Tesfaw, et al. (2022), “Welding is a basic manufacturing process for making components or assemblies.” or to Lee, et al. (2021), a welding process is “...used for joining or repairing metal parts using controlled equipment.”. Due to the repeated melting and cooling processes, quality issues might be found, such as layer misalignment, dimensional errors or residual stress generation.

One of the most important aspects regarding the quality inspections is their periodicity. Regarding the welding control, in BS 1140 (1993) standard, this periodicity is defined as follows:

1. As soon as it is practicable in the beginning of each shift/daily work period;
2. At the end of each shift/daily work period;
3. Immediately after alterations in the machine settings;
4. Immediately after any alterations of any material supply source;
5. Immediately after and before new electrodes are fitted.

There are several types of welding processes. In this section, both metal active gas (MAG) welding and spot welding will be defined in terms of process and in terms of recommended quality control examination.

MAG welding

MAG welding is the most common arc welding method in the industrial field, due to its economical-efficiency and practicability-efficiency ratios. This type of welding is a mechanical-metallurgical process, in which the final quality of the weld depends on many parameters such as the weld metal deposition and penetration, the fusion angle and the wetting (Mausam, Sharma and Chaturvedi, 2022) (Simsek and Akkus, 2021).

Nowadays, there are several inspection methods that might be applied to the welds, in order to analyse their final quality. These methods are purposed in ISO 15614-1 (2017), that recommends two levels of inspection, one less (level one) and one more restrictive (level two). Considering level one, a 100% visual control is recommended, together with a macroscopic examination to a specified sample. At level two, more inspection examinations are suggested, arising the execution of non-destructive tests, that allow the testing of parts without destroying the welds. These tests allow the identification of "...cracking, porosity, incomplete penetration, inclusions, as well as a lack of sidewall fusions and similar defects." (Kah, et al. 2014).

Regarding the non-destructive tests, two methods are purposed in order for each company to choose the most suitable for its production: the radiographic and the ultrasonic testing. These two methods are considered to be two of the three most efficient ones (Kah, et al. 2014). Currently, the best method for non-destructive weld inspection is the phased array ultrasonic test (PAUT). As claimed in a study by Huggett, et al. (2017), when comparing both X-ray radiography and a calibrated PAUT system, it was found that PAUT is able to "...cover defects less than 0.2 mm where X-ray radiography could not."

Spot welding

Spot welding is a complex thermal-electrical process as it depends on mechanical, electrical, thermal and metallurgical factors, making the welding quality function of several process conditions, such as noise, errors and interaction effects (Zhao, et al. 2021). As so, it is important to define inspection procedures after this process, in order to guarantee the weld quality. These qualifications of procedures are stated in ISO 15614-12 (2014), being advised for resistance spot welding, three test types: shear test, adhesion test and visual examination. For each test, the sample number is also suggested.

2.3.3. Quality control after electrostatic powder painting

As claimed by Jozsef and Blaga (2015), "Electrostatic painting is part of the activity of treatment, coating and decoration of metal surfaces.". According to Murid, et al. (2022), in this method, "...powder particles are charged by passing through an ion-rich region, which repel each other to produce an evenly distributed coating.". Thus, "Electrostatic coating is being developed as an attractive alternative to overcome the problems encountered during conventional coating which includes non-uniform coating, dust generation, high energy and time consuming, equipment cleaning, and operating expenses.". In Figure 7, it is possible to observe the process mapping of a common electrostatic powder painting procedure.

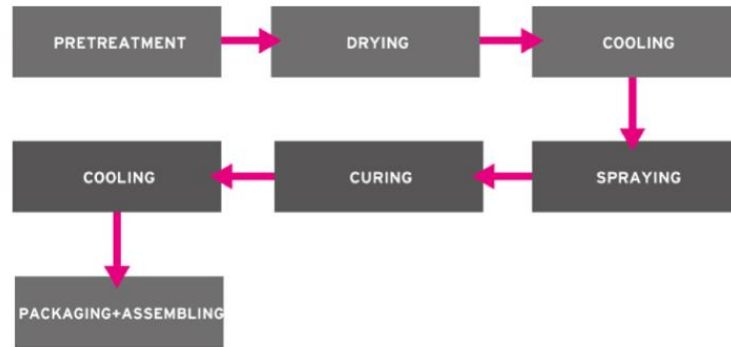


Figure 7: Process mapping of a common electrostatic powder painting process (Ayrilmis, 2022).

The non-conformities that emerge after this process might be divided into two main groups. The first one covers the simple defects that arise in the product's appearance, such as scratches, different shades, spots, impurities in the layers of paint, etc. The second one covers the defects with a long-term impact, such as the development of rust, the peeling of the paint, the impact resistance, etc. These non-conformities can be due to different causes, from both paint and raw material quality to the chemical pre-treatment or curing quality (Jozsef and Blaga, 2015).

There are several quality control tests that might be done before and after the electrostatic powder painting process, which are defined in ASTM D3451 (2017). However, this standard states that the "Selection of methods to be followed must be governed by experience and the requirements in each individual case...". Thus, by combining the information of the standard with the information presented by Jozsef and Blaga (2015) and by Danick (2000), it is possible to state that, within all the parameters that might be inspected after this process, the most common ones are the gloss, the paint thickness, the hardness, the impact resistance, the adhesion and the flexibility to bending.

2.4 Lean manufacturing

Lean manufacturing is considered to be, according to Anvari, et al. (2011), "...a philosophy of production that places emphasis on the minimization of the amount of all the resources used in the various activities of an enterprise.", by the recognition and the elimination of its non-value-adding activities. This approach allows an increase of quality, the reducing of costs, on-time deliveries, within others, leading to an easier adaptability to the market evolution and to the achievement of competitiveness among other manufacturers.

2.4.1. Lean manufacturing and quality control

As part of the *Lean* manufacturing mind-set, quality itself represents an important paradigm shift. Before this mind-set, quality control corresponded to a "...random inspection of lot samples or lot-based statistical quality control methods...", being actions that added no value to the company (Sundar, Balaji and SatheeshKumar, 2014). For example, the acceptance sampling, presented in the previous section, is considered only to "...reinforce the conformance-to-specification..." and not to give "...any feedback into either the production process or engineering design or development that would necessarily lead to quality improvement." (Montgomery, 2009). Baudin (2002) also states that "...inspections are waste...".

Thus, the *Lean* quality control approach aims to "...avoid sampling as a disruption of production routines...", in order to focus on "...checking 100% of the units but doing it in a way that does not slow down production." (Baudin, 2002). The way of ensuring the

conformance of the products has changed: the traditional approach was to assure the quality of the final product, that is, the controlling of “...the product at the end of the production system, before it is delivered to the client” (Nóvoa and Faria, n.d.). Now, the highest levels of quality are obtained by a real time detection or prevention of errors at their source, by the implementation of different techniques, such as auto control or false-proofing (Sundar, Balaji and SatheeshKumar, 2014), which translates into the implementation of a new approach: process controlling. It is important to enhance that several of these ideals and concepts are based on the Toyota Production System (TPS) philosophy.

Besides this, it is believed that “Excellence in quality is not merely delivering the required output to the customers, but a management strategy to enhance and align the processes in a way that excellence becomes inherent part of the ways of working.” (Sunder and Antony, 2017).

With regard to the auto control, as it is stated by Ortiz and Park (2011), ideally, every single operator on the shop floor should be able to use different process control methods to guarantee the quality of the products that pass through themselves. Also, according to Baudin (2002), “... each assembler is responsible for the quality of his or her work.”. In this way, the quality controllers would only have, in-process, a review role. This type of operative mindset is considered to be reactive, rather than proactive: the quality controllers have the objective to plan, instead of reacting to the current crisis of the shop floor (as if they were “firefighters”). This means that rather than “...applying treatment for a symptom”, they are aiming to resolve the “...underlying disease.” (Ortiz and Park, 2011).

In the following sections, some quality control tools of the *Lean Manufacturing* paradigm are described. They belong to specific stages of the *Lean* methodology implementation, that are presented in Figure 8.

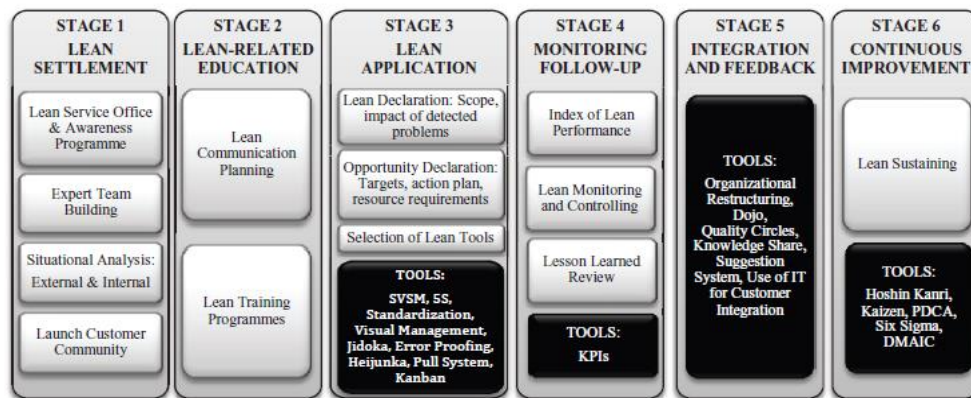


Figure 8: Lean implementation stages and respective tools (Andrés-Lopéz, González-Requena and Sanz-Lobera, 2015).

Standard Work

One of the most important *Lean* tools used in the quality field is the work standardization, that belongs to the stage 3 of the *Lean* implementation procedures: *Lean* Application. It corresponds to the establishment of precise work procedures for each one of the operators involved in a specific process, also known by the acronym SOP (standard operating procedure) (Santos, Santos and Santos, 2021) (Schonberger, 2019). The work standardization allows “...processes to be completed in a consistent, timely, and repeatable manner...”, enabling variability elimination (Lu and Yang, 2015).

Poka-Yoke

Another quality technique of the *Lean Manufacturing* quality control is the *Poke-Yoke* system. As part of the *Jidoka* mindset, it also belongs to the stage 3 of the *Lean* implementation procedures.

Developed by a Japanese engineer, *Poka-Yoke*, also known as fool-proofing or mistake-proofing, is a technique used with the objective of achieving zero defects and the lowest quantity of quality control inspections possible (Wijaya, et al. 2020). It is considered to be a preventive method, aiming the identification and the elimination of problems, mainly in the critical stages of the manufacturing processes, as an assistant device, mechanism or solution in errors detection (Palange and Dhatrak, 2021). As part of a continuous improvement strategy, *Poke-Yoke* allows not only to improve the quality levels of the final product, but also to increase both productivity and efficiency of the company (Galan and Janta, 2019).

Hirano (1988) presents, in his book, 240 examples of *Poka-Yoke*. For a better understanding of these systems, a simple example will be presented. The process consists in the assembly of plastic cassette covers with screws. In Figure 9, it is possible to observe the initial screw that presented the problem: the screwdriver frequently slipped out of the slot, making scratches in the plastic covers. In order to resolve this, a change was made in the shape of the screw slot, that allowed the total elimination of the scratches caused by this process.

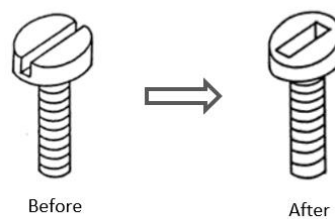


Figure 9: Introduction of *Poka-Yoke* concept into a part of the shop floor (Hirano, 1988) (edited).

Considering these systems, it is important to define the roadmap for their implementation. According to Dudek-Burlikowska and Szewieczek (2009), a practical example from an automotive company is presented, a type of industry that has both manufacturing and assembly sectors. In their approach, the implementation of a *Poka-Yoke* system only makes sense if, considering the product or process where the defect occurred, that product or process is already documented and it is confirmed that those documents have been respected. If not, then the problem solving must, first of all, consist in the setting of documents, standards, instructions and guidance. If these documents are consistent and are being followed and there are still errors and defects occurring, then the introduction of a *Poka-Yoke* system might be considered. The purposed roadmap for the *Poka-Yoke* implementation is presented in Figure 10 (SPT refers to the set of documents, standards, instructions and guidance).

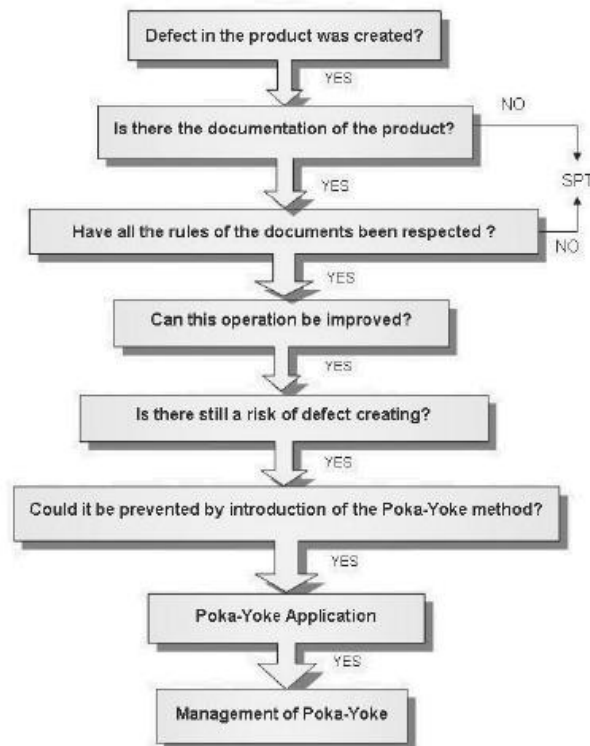


Figure 10: Roadmap for *Poka-Yoke* implementation (Dudek-Burlikowska and Szewieczek, 2009).

Quality Circle and 8D report

Finally, another relevant *Lean* quality tool is the quality circle, that belongs to the stage 5 of the *Lean* implementation procedures: Integration and Feedback. One of the most important pillars of continuous improvement is teamwork and “...no one better knows the problem associated with its work than the person who does the work...” (Palange and Dhattrak, 2021). As so, quality circles have the objective of promoting the brainstorming within the teams and to encourage employees to make their own improvement proposals, what guarantees a sustainable quality assurance strategy (Romero, et al., 2019) (Andrés-López, González-Requena and Sanz-Lobera, 2015).

Often associated with the quality circles is the 8D report. This is a tool used to solve incorrect quality of products problems, by a deep causes’ analysis and the consequent brainstorming on actions to reduce or eliminate the problem (Zasadzień, 2020).

2.4.2. *Lean* manufacturing and *Industry 4.0*

As stated by Bittencourt, Alves and Leão (2021), *Industry 4.0* is “...a way of promoting competitive advantages through the application and integration of new technologies.”. It is an approach “...characterised by the strong connection between processes, products and services, represented by the Internet of Things (IoT) and its high level of integration forms a network that links both physical and virtual space...”.

As two important paradigms of today’s manufacturing sector, it is possible to state that both *Lean* and *Industry 4.0* concepts are connected. On the one hand, *Lean* tools “...such as work standardization, organizations and transparency are fundamental in supporting the implementation and consolidation of the *Industry 4.0*.”. On the other hand, the use of *Industry 4.0* technologies might solve problems and discover better ways to work, leading into the *Lean* mindset (Bittencourt, Alves and Leão, 2021). Moreover, according to Gallo, et al. (2021), “the concept of *Industry 4.0*, inside of the companies, is nothing if it doesn’t integrate

with the concept of *Lean* Production.”: the integration of both concepts allows the reducing of the risk associated to the high implementation costs of *Industry 4.0* technologies.

In the following sections, some *Industry 4.0* technologies that might be associated to a *Lean* quality control are presented.

Pick-by-light Systems

When talking about *Lean* manufacturing, one of its main objectives is to make the information easily accessible, that is, “... communicated in a succinct way...”. In order to achieve this, and together with the *Industry 4.0* paradigm, *pick-by-light* systems are being, nowadays, more and more used in the competitive industries of manufacturing. *Pick-by-light* is a guided picking method in which the picking information is presented in a visual way: it is usually constituted by a lamp that lights up and indicates the right removal shelf/box; by a display that shows the right quantity of parts to be taken; and by a button/sensor that confirms the removal. In Figure 11, it is possible to observe the functioning of one of these systems (Baechler, et al. 2016).



Figure 11: Functioning of a *pick-by-light* system (BannerEngineering, n.d.).

According to Baudin (2002), the idea of *pick-by-light* systems is to “...direct the picker’s eyes to the right items and quantities by means of LEDs located next to each bin.”. By guiding the operators to pick the right parts, in the right quantities and in the correct sequence, it is possible to state that *pick-by-light* systems prevent human errors, what makes them one type of *Poka-Yoke* systems. Besides preventing errors, these systems also increase the productivity of manufacturing as they eliminate the dead-times of checking and re-checking instructions: they relieve the operators from “...having to find the items on a pick list.” (Baechler, et al. 2016) (BannerEngineering, n.d.) (Baudin, 2002).

In the picking literature, other methods are purposed, such as *pick-by-paper* (manual method in which the operator uses a paper sheet – picklist - with all information on it and a pen), *pick-by-display* (digital *pick-by-paper*, where the information is provided on a mobile terminal with a display) and *pick-by-projection* (parts are augmented by an assistive system constituted by projectors, depth cameras and scale). To compare the four methods, it was important to analyse the quickness, the error rate and the task load of each method. Considering both the task completion time (Figure 12 - left) and the task load (Figure 12 - middle), it was possible to state that the *pick-by-light* method led to the best values, that is, the lowest ones. Regarding the error rate (Figure 12 - right), *pick-by-projection* led to the lowest value but followed by *pick-by-light*. Thus, by making a general comparison, *pick-by-light* is considered the best current picking method (Baechler, et al. 2016).

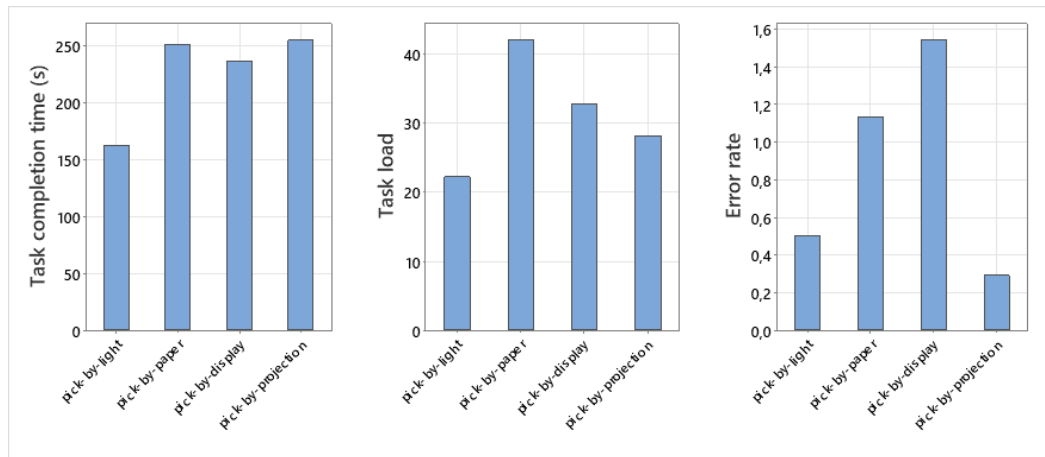


Figure 12: Parameters' comparison of different picking methods (Baechler, et al. 2016).

RFID Systems

Another *Lean* important strategy is the traceability of products within the companies. According to Escalona, Koch and Garcia-Borgoñon (2022), traceability is the "...ability to chronologically interrelate uniquely identifiable entities in a way that matters.", being "...strongly recommended in industrial standards.". Traceability might also be referred to as "...tracking the geolocation of products throughout the manufacturing steps and how that functionality can foster further optimization of the manufacturing processes." (Beliatis, et al. 2021).

When combining both *Lean* and *Industry 4.0* paradigms, there is the arising of the digital traceability technologies: within the manufacturing sector, these enable the tracking of assets in the production, allowing a higher accuracy and controllability and also allowing a reduction of the labor costs, by the identification of problems in real time (Beliatis, et al. 2021).

Nowadays, one of the most used digital traceability technologies are the Radio Frequency Identification (RFID) systems. They consist in the contactless and automatic asset identification, by the collection of data with technology based on radio waves, enabled by a transmitter/receiver relation. An information management system is also required in order for data processing to be possible. These systems are constituted by a tag (Figure 13 – marked in red), that is attached to the part and that contains a unique code; and by a tag reader (Figure 14), which receives the data from the tag by emitting radio waves to it. Then, the reader sends back the received data to the information management system (Beliatis, et al. 2021).

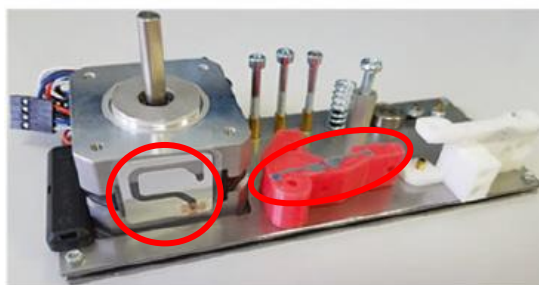


Figure 13: RFID tag implementation into the assembling parts (Židek, et al. 2020).



Figure 14: RFID reader installed in a roller conveyor (Dastres, Soori and Asamel, 2022).

As claimed by Dastres, Soori and Asamel (2022), RFID systems are considered to be the bridge between the ERP system and the manufacturing floor itself, helping to improve several aspects, within which the quality control by avoiding product shortages. As reported by Nosenko, et al. (2019), such systems are a requisite for a quality control in full, being “...particularly effective for assembly plants, where the account of a large number of materials and components in all technological and controlled operations are the key factor to improve the efficiency of the organization and production planning.”. The assembly identification enabled by the RFID system is not available for small assembly parts such as nuts, screws or washers. Thus, these parts can only be inspected by visual systems (Židek, et al. 2020).

Business Intelligence

Finally, another relevant Industry 4.0 technology is the Business Intelligence. According to Miguéis (2022), “Business Intelligence (BI) refers to the procedural and technical infrastructure that collects, stores, and analyses the data produced by a company's activities.”. Whereas, previously, BI was only worked on by IT specialists or Data Analysts to the end user, nowadays, BI is easily accessed by everyone. It is becoming an essential tool for any enterprise when it comes to “...visualize, analyse and prepare the strategic planning for the future.”, working as a decision making method. As it is very difficult to sensitively interpret raw data, BI allows its efficient visualization with the help of different technologies (Gowthami and Kumar, 2017) (Kumar and Belwal, 2017).

Currently, there are several BI tools in the market. One of the best known and used is the *Microsoft Power BI*. While having a friendly and simple user interface, this application allows the creation of dynamic dashboards for “...modelling scenarios and complex data mash-up.” (Gowthami and Kumar, 2017). In Figure 15, it is possible to observe the data flow of *Power BI*. The input data might come from several data sources, such as *Microsoft Excel* workbooks, SQL servers, XML files, JSON files, etc. The output corresponds to the user accessing to dashboards in different devices, such as mobile phones, tablets or computers.

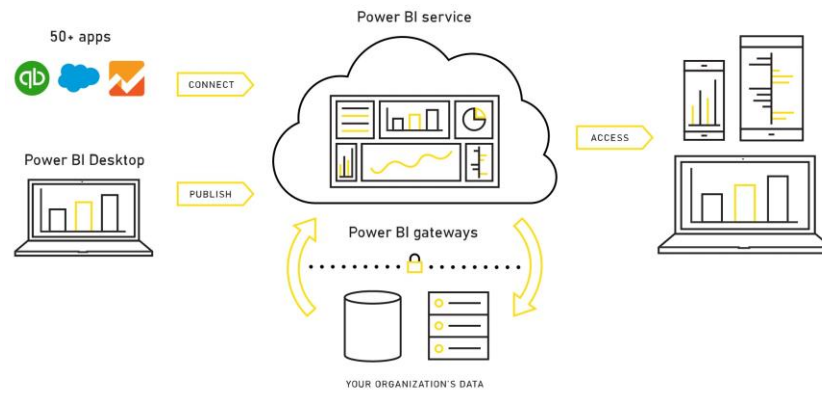


Figure 15: *Power BI* data flow model (Gowthami and Kumar, 2017).

3 Current state description

Nowadays, manufacturing, the transformation industry, is known for being one of the most global competitive areas. It demands costs reduction, by both inventory reduction and process, time and quality optimization. This necessity also emerges from the fact that the actual paradigm has changed from what it was a mass production, to a mass customization: this means that the life cycles of the products are decreasing more and more, resulting in the growth of the necessity of a smaller and smaller time-to-market. In order to achieve this, it is compulsory to find solutions that enable a quick (real-time) and effective response to the client demands, without compromising the products' quality.

3.1 General conception and production flow description

As a company that is focused on keeping up with its competition, *Schmitt Elevadores* is devoted in the implementation of *Lean* and continuous improvement methods and principles. Among its market, the company has already clear advantages by using this type of mind-set. Currently, it is the only Portuguese company, within the elevators manufacturing industry, that while having an elevators' catalogue, it is focused on the customization of their products, meaning that the client is able to fully customize the product he is buying. Thus, the design, conception and production processes of the elevators start after the customer order, that, within others, is able to choose the types of materials of the product, the number of levels required, the doors type and the size and capacity of the elevator.

The process flow starts at *Schmitt 1*, at the mechanical and electrical departments, that design the model of the elevator and create its bill of materials (BOM). Once these models are approved, the production order is released, by the ERP system of the company, *Microsoft Navision*. The responsibility passes then to the planning department (O1) and, consequently, to the preparation department (PEP), that is responsible to plan the production of parts that are produced internally. In order to respond in real time to the clients' customization demands, the company has zero stock of finalized elevators. This means that PEP has to plan the production in order to guarantee that the ordered product is finalized in the day it is going to be issued (day N).

Regarding *Schmitt 1* production, there is only one production section: Electrical Assembly (P42).

Regarding *Schmitt 2* production, PEP has to guarantee that the production of one elevator starts exactly four days before its issue (day N-3). This means that, at the moment, one elevator is taking four days in *Schmitt 2* production to be completed, being that each day corresponds to a different process of the production: the raw-material starts to be transformed in day N-3 at Mechanical Transformation section (P10), then in day N-2 it goes through the Welding section (P20), in day N-1 it is passes through the Painting section (P30) and, finally, in day N it is assembled and packed at the Doors Assembly section (P41) and at the Car and Shaft Assembly Section (P43).

The manufacturing sections of the company and its inputs and outputs are organized and presented in a simplified way in Figure 16.

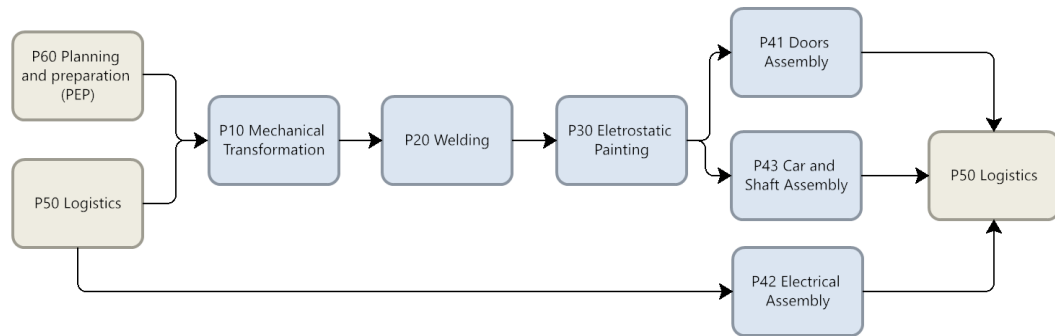


Figure 16: Schmitt Elevadores simplified process flow.

At P10, raw materials transformation, the different material sheets (Table 2) suffer two types of mechanical transformations. Initially, the sheets go through a cutting process, that might be mechanical (in a punching machine, up to 1,5 mm of thickness) or by laser. On the one hand, carbon dioxide (CO₂) laser is used for sheets up to 15 mm of thickness; on the other hand, nitrogen (N₂) laser is used for more sensible sheets, up to 2-3 mm of thickness.

Table 2: Raw material sheet types that enter *Schmitt 2*.

Raw material sheet types
Cold rolling steel
Hot rolling steel
Stainless steel
Coated steel: zincor
Coated steel: PVC (<i>Lampre</i>)

Still in P10, after the cutting process, 60-70% of the parts need to be bended. For this process, there are four available machines: two bending presses and two turning presses. The difference of both machines is that the turning one is more automated, as the machine itself turns the part so that it can be bended in both directions. As so, it is used for pieces with a higher volume, in order to facilitate the operators' task.

At P20, transformed parts that come from P10 are welded. Some small specific technical tasks, such as profiling or threading are also done at this section, but, due to the low percentage of parts that go through them, this project will focus only on the welding processes. The welding section is divided into seven cells: five for semi-automated MAG (non-standardized parts); one for automated MAG (with a robotic arm - standardized parts); and one for spot welding, that enables higher frequencies of welding. Each one of the semi-automatic MAG cells is responsible for different parts of the elevator: the first and second are dedicated to the shaft parts; the third to the car floors; the fourth to the car ceilings; and the fifth to the doors and to special materials' welding (such as stainless steel).

At P30, parts that come from both P10 and P20 go through an electrostatic powder painting process. This section is constituted by an automated carousel that leads the parts through the different steps of the process. The parts are loaded by one operator and then go across a degreasing tank: the impurities are firstly removed and then the parts pass through two key nanotechnological processes - phosphatising and passivation. Before leaving the

tank, they are cleaned with tap water. After leaving the tank, the parts cross the first oven (100°C), aiming to be fully dry before reaching the painting cabin, where they are painted by a robot and, if needed, by one operator, that is responsible to paint unreachable surfaces for the robot. Finally, the parts go through the second oven (polymerization tunnel – 245°C), where they stay for around 10 minutes. The parts are cooled at environment temperature and are then unloaded from the carousel by one operator. Currently, the velocity of the carousel is determined to be 1 m/s and one part takes around 3h30min/3h40min to go through the entire process.

Finally, the parts go through the different assembly processes in P41 and P43. The parts that are assembled in these sections come not only from the previously presented sections but also from the warehouses or from the shop floor's border line.

P41 corresponds to the section in which the doors of the elevators are assembled and packed. After this section, the packages are responsibility of the logistics department, that deal with their expedition. P41 is divided into five different cells, that assemble different components of the doors:

1. Door sheets;
2. Door frame and sills;
3. Landing top tracks and accessories;
4. Box top track and microport;
5. Packing.

P43 corresponds to the section in which the car and the shaft equipment of the elevator are assembled and packed. As in P41, after this section, the packages are responsibility of the logistics department. P43 is divided into nine different cells:

1. Cars' floors and ceilings: preparation of coatings, illuminations and protective buffer rails;
2. Car's preassembly: panels, protections and mirrors;
3. Pit elements: slings and fixations;
4. Chassis, tension weight and supports;
5. Counterweight and uprights;
6. Machines and motors (for elevators up to 630 kg; for heavier elevators, they are bought directly from a supplier);
7. Rope cutting;
8. Accessories kits;
9. Hangers.

In Appendix B it is possible to observe the floor plan of *Schmitt 2* shop floor. The detailed flowchart of *Schmitt 2* production is presented in Appendix C.

Returning to *Schmitt 1* production, P42 corresponds to the section in which the electrical components are assembled, electrified and programmed. The input of the process is a *Kombox* car, that is equipped with components from the warehouse for one single elevator. Apart from the warehouse, other parts to be assembled come directly from the shop floor's border line. This section is divided into twelve different cells:

1. Modules assembly;
2. Modules electrification;

3. Cables cutting;
4. Car operative panel and landing call station assembly;
5. Shaft assembly;
6. Borne assembly;
7. Accessories;
8. Mechanical components;
9. Electromechanical assembly;
10. Car equipment;
11. Final equipment testing;
12. Packing.

It is important to note that cell 08 (mechanical components) corresponds to a cell that supplies almost exclusively *Schmitt 2* production. The average output of P42 is around 6 elevators per day. The detailed flowchart of P42 is presented in Appendix D.

3.2 Quality control: controllers, methods and techniques

Considering the objectives of this dissertation, it was necessary to understand the work that was currently being made by the *Schmitt Elevadores* quality controllers and also the quality control strategies that were being used in each division of the company's production. It is important to enhance that the company is currently certified with the ISO 9001, the international standard that specifies requirements for a quality management system.

In this section, these methods will be presented, having into account the sector they are occurring on. The general quality indicators used for quality control in the company are also described.

Quality controllers

At the present, *Schmitt Elevadores* has two quality controllers, which function is to control the quality of the company's products. The first one – S1+ controller – works in *Schmitt 1* and has his basis at the electrical warehouse. He is the responsible for the quality of the products that enter the company from the suppliers, of the parts in process in P42 and of the ones that will be dispatched from *Schmitt 1* (both P42 assembled elevators' electrical parts and spare parts shipments). His current objective is to make, approximately, 70 controls per day, divided by entrance controls, in process controls and dispatch controls.

The second one – S2+ controller – works in *Schmitt 2*. He is responsible for the quality of the mechanical production raw materials (different material sheets, as seen in the previous section), for the parts in process in P10, P20, P30, P41 and P43 and also for the assembled elevators' parts that will be dispatched from *Schmitt 2*. His current objective is to make, approximately, 90 controls per day (around 40 at the entrance, 40 in process and 10 at the dispatch).

As every operator of the company, each controller has 8 labour hours per day, which means that, per week, 80 hours should be dedicated to quality control within the company.

Suppliers' material receiving

The receiving of materials from the suppliers happens both in *Schmitt 1* and *Schmitt 2*. In *Schmitt 1*, all the electrical components and the mechanical parts that are not produced in the company are received. In *Schmitt 2*, the main product that enters in the shop floor is the raw material of the production, that is, the different material sheets, profiles, etc.

On the one hand, at *Schmitt 1*, the supplied products are received at the electrical and mechanical warehouses. The operator responsible for receiving and registering the just arrived parts is also responsible for counting them, aiming to check if they are according to the purchase order. This operator is able to make the registration, in the ERP *Navision*, of almost all products that arrive to *Schmitt 1*, with the exception of chemical products, such as sprays or lubricants. If the warehouse operator tries to register one of these products, the system will show him a message, telling him that that product needs a special verification from an office operator of the Quality, Security and Environment department (QMB). This operator verifies, mainly, if the needed labels are correct or not. Alternatively, if the arrived product is a mechanical or electrical one, the operator is able to register it and let it enter the warehouse. This is where the S1+ controller starts the quality assurance process.

The quality control method to be applied is based on the type of product on analysis: if it is a plating or turning material, then it requires a dimensional control; if it is not, the only control made is a visual one. It is important to state that there are not any type of working instructions regarding the at entrance quality control: the samples are picked randomly from random batches and, currently, the only stipulated standards are not being followed, with regard to the quantity of pieces that should be controlled considering the size of the batch – MIL STD 105E. Besides this, even if a product is non-compliant, it still might pass on the quality control verification if its function is not compromised.

On the other hand, in *Schmitt 2*, there is no quality control of the incoming raw material. The logistics operators inform the S2+ controller if they see something unusual, but, otherwise, there is not any type of quality control.

P10

At P10 there are no standardized processes of quality control. The only procedure that might be made is done by the operators at the bending machines, that have access to measure equipments, such as calipers or measuring tapes, and that might use these instruments if something visually seems non-conforming to them. Regarding the S2+ quality controller, he randomly inspects the parts in terms of burrs (Figure 17), scratches, sheet deformation due to high internal tensions and deviations on the bending angles.



Figure 17: Non-compliant part due to excessive burr.

P20

At P20, as in the previous section, there are no standardized processes of quality control. The only procedure is made by the S2+ controller before the process itself. Randomly, he takes some set of pieces that are meant to be welded and verifies if its unions are well fitting.

P30

Differently from the previous manufacturing sections, P30 has determined quality control procedures. The head of section is responsible for checking, every day, if the painting thickness of four random pieces is within the specifications ($90 \pm 30 \mu\text{m}$), following the ASTM D3451 requirements. He is also responsible to check, two times per week, the pH and the temperature of the tank mixture, guarantying, by comparison, the correct operation of the available probe. He also makes the control of the water of the washing tank: this water should be changed one time per week; however, this is currently not happening, in order to reduce both costs and wastes. Thus, the head of section is able, through his experience, to define whether the water should or not be changed. Besides these controls, one external company comes to the shop floor one time per month to take a sample from the tank's mixture, aiming to analyse the bath and to communicate if it is within the specifications, if it is reaching saturation or if it is already saturated. Finally, the S2+ controller makes random visual verifications, aiming to detect possible not painted spots.

P41

As in the previous manufacturing section, P41 is currently using quality control strategies (mainly *Poka-Yokes*) during both assembly and packing of the elevators' doors. In every cell of this section, the operators have access to magnets, which allow them to verify if they are picking pieces of the right material: different steels have different iron concentrations, making the magnet attraction to vary. Alert labels (Figure 18) are also present in each cell, and when applied, they mean that that specific elevator has a particular need or specification.



Figure 18: Alert labels used in P41.

Considering now the particular cells, in the first one, each operator has access to an aluminium profile: as a piece that is manufactured by extrusion, its calibration is guaranteed, so it is used for checking the flatness of the inspected door sheets. At the door frame and sills cell, every rip where the main command will be assembled is measured with a metric tape, to guarantee the demanded specifications: this happens due to the associated risky picking, as rips from different elevators present small size variations. This cell is also using some *Poka-Yoke* tools, in order to guarantee the alignment of the assembly parts (for example, the correct alignment of screws – Figure 19) and to guarantee the quality of the welded parts, with the help of a sliding shoe.



Figure 19: Poka-Yoke system used in P41 for screws alignment.

At the third cell, a weight label is available and is set into the material in order to remark that that specific landing door needs a closing weight (in opposition to a closing spring). At the fourth cell, a microport label is available and is set into the material in order to remark that, for that elevator, the microport must be sent apart. Finally, at the packing cell, three pictures of the package are taken and transferred to the computer. However, these pictures only work as a proof to respond to non-conformities complaints and not as a real quality control method.

P42

As it was stated in 3.1, P42 has a cell fully dedicated to the testing of the final equipment of the section and also has multiple test boxes within the different cells, that allow the verification of the electrical components and their correct assembly.

As for quality control strategies, in the electrification cell, there is the verification of both tightness and isolation of the multiple modules of the elevator (SU, of service, of cabin, of power, etc). There is also the verification of the amperage of the switches/differentials. Over the process, if there is some component that is missing, each operator is responsible for filling a sheet specifying the name of the component that is missing, so that there is no packaging without it. Finally, before the equipments are finally packed, the S1+ controller might come and make some verifications: components' sizing, tightness of wires, buttons and key rotation verification, high voltage labels, etc. While doing this, he writes down the components' information in a sheet of paper that guides him through the components he needs to inspect (Figure 20).

PRODUÇÃO			
Nº Obra >			
1 Cabo de manobra			
2 Fita magnética			
3 Fita magnética axial			
4 Fim de curso			
5 Cortina fotoelétrica			
6 Armadura retangular	2	2	
7 Botoneira de patamar			
8 Botoneira de cabina			
9 Cabo DCP			
10 Cablagem (Aperto)	1	1	

Figure 20: Sheet layout for P42 in process control by S1+ controller.

P43

As in P41 assembly section, P43 is currently using some quality control strategies (mainly Poka-Yokes) to prevent errors within the section. In the first cell, there is a test box that allows the verification of the car's illuminations (their operation and colours). In the fixations cell, the workbench is divided by labels, in order to prevent kits' exchanges. In the

ropes cutting cell, every cable is weighed and a label is put in each cable, by the operator, in order to make a registration confirming that the cable is within the specifications. In the accessories cell, the operators are distinguishing the different kits of small and look alike accessories by putting coloured stripes into the labels (Figure 21).

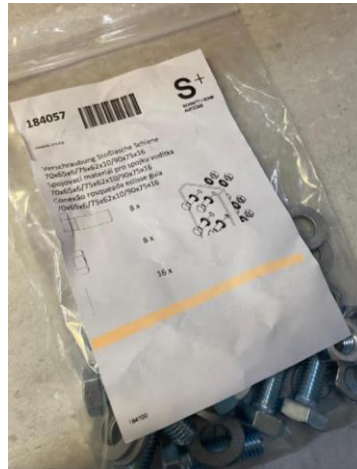


Figure 21: Coloured stripes as a mistake-proofing system in P43.

Regarding the hangers' cell, it was considered that the hangers are critical equipments, due not only to the number of non-conformities the company was having of this particular part of the elevator, but also because their well-functioning is compulsory for the elevators' door opening and closing. As so, it was defined that each hanger leaving *Schmitt Elevadores* should be verified by the S2+ controller: he verifies around ten hangers per day and labels them with special labels (Figure 22), signed and dated by him. He also takes pictures of every label and elevator number, in order to have a proof that that specific hanger was verified.



Figure 22: Label for hangers after quality control in P43.

Finally, during the packaging processes, the operators are responsible for taking pictures of the assembled parts within the packages, but, as in P41, these pictures only work as a proof to respond to non-conformities complaints and not as a real quality control method. In the panels cell, during the packaging, a four eyes verification is made (two operators make the verification process and write down their operator number into the package).

Before expedition

The quality control processes before expedition are made by both quality controllers. The S1+ controller is controlling both the spare parts shipments and the electrical parts that come assembled from P42. The S2+ controller is controlling the mechanical parts that come assembled from P41 and P43.

On the one hand, regarding the control of the spare parts shipments, the S1+ controller goes to the spare parts warehouse and verifies if the packages that will leave to the delegations have the right shipment number, if the quantity inside the package corresponds to the ordered quantity and if the address of the shipment corresponds with the name of the delegation chief, in order to avoid delegations' exchanges.

On the other hand, both controllers assure the state of the packed assembled parts from production: they verify if the packages are within the standards, by visual checking not only the state of the package itself but also the number of staples within the package and their alignment with the planks.

Quality Indicators

Currently, the main quality indicator is the number of quality controls made per year. This means that the company established one specific number of quality controls that, together, both quality controllers must achieve for one year. In Table 3, it is possible to observe the evolution of the control numbers of the last three years. In addition to this indicator, two other relevant ones should be highlighted: the number of non-conformities and the non-quality costs associated to each.

Table 3: Evolution of the number of controls per year.

Year	2019	2020	2021
Number of controls	32 388	30 570	37 396

3.3 Non-conformities analysis

Aiming to perceive the main, the most current and the most frequent quality problems of the company, in this section, an analysis of its non-conformities from January 2021 to March 2022 will be presented. From this analysis, the main objective is to be able to specify the critical suppliers of the company and also its critical production sections, that will convey on the sections in which more investments should be done to improve the quality control system of the company. It is important to state that there are two main types of non-conformities: *Pns*, non-conformities that are detected before expedition; and *NCFs*, non-conformities that are detected after expedition, mainly in delegations or at the elevators' installation, which means that this type of non-conformities is more critical to the company. An analysis to the non-quality costs of the company is also presented.

As the first step of this analysis, the quantity of non-conformities that are considered to be within the scope of the project was determined: as it is possible to observe in Figure 23, in the considered period of time, 32% of the *Schmitt Elevadores* non-conformities were production's responsibility and 31% were supply chain's responsibility. This means that 63% of the total non-conformities of the company are relevant to the project. The remaining 37% correspond to out of scope non-conformities, that are responsibility of other departments, such as the technical ones, development, logistics or even the delegations themselves.

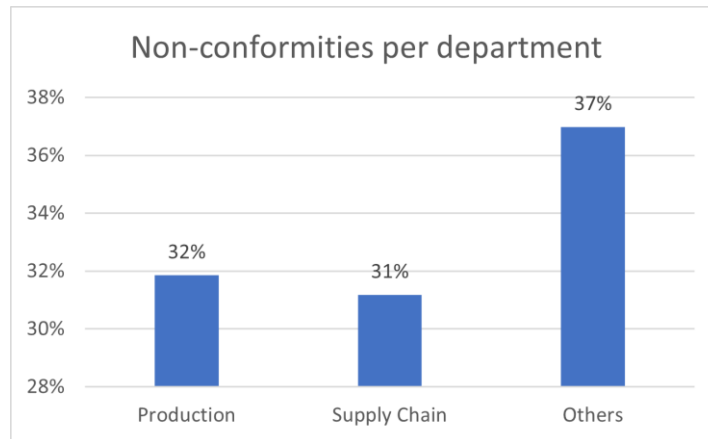


Figure 23: Number of non-conformities per department, from January 2021 to March 2022.

3.3.1. Critical suppliers' analysis

Firstly, the supply chain's non-conformities were analysed. In order to understand which are the critical suppliers of the company, that is, the suppliers that are associated to the highest numbers of non-conformities, the given data was analysed and is presented in Figure 24. It is possible to verify that the most critical supplier of the company is *F10*, with a value of 27% of the total suppliers' non-conformities. Other suppliers might also be considered to be critical, as they represent values from 2% to 5% of the company's total suppliers' non-conformities.

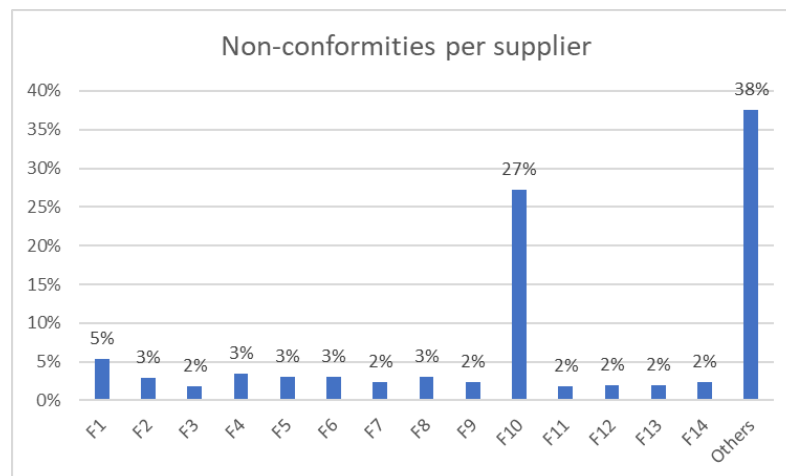


Figure 24 Number of non-conformities per supplier, from January 2021 to March 2022.

3.3.2. Critical production sections' analysis

Considering the non-conformities that are responsibility of the production, it was important to divide them into the different production sections. As it is possible to observe in Figure 25, the sections that present more non-conformities are the mechanical transformation and the assembly ones.

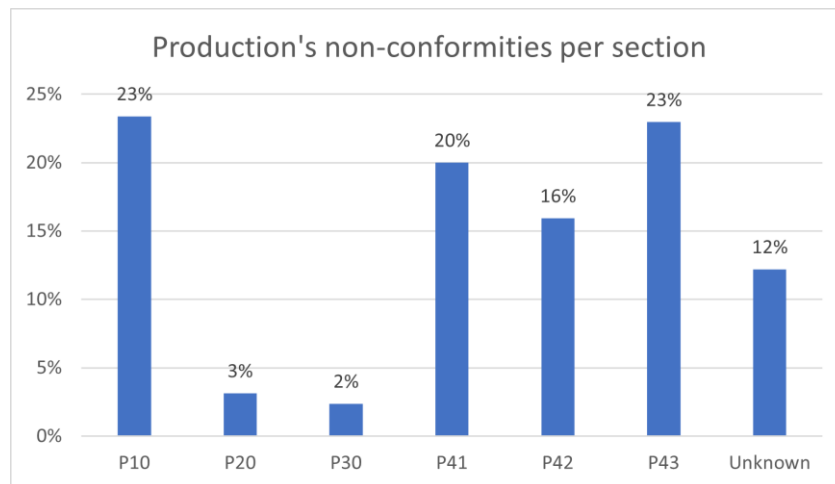


Figure 25: Number of non-conformities per production section, from January 2021 to March 2022.

However, this analysis is not enough to determine the most critical sections of the company: in order to go deeper into this analysis, the same non-conformities were analysed, but having into account the difference between *Pns* and *NCFs*. As it is possible to observe in Figure 26, while the mechanical transformation has a very high percentage of *Pns*, the assembly sections exhibit the opposite, presenting very high percentages of *NCFs*. This means that, after all, the assembly sections present a higher level of criticality than the mechanical transformation does.

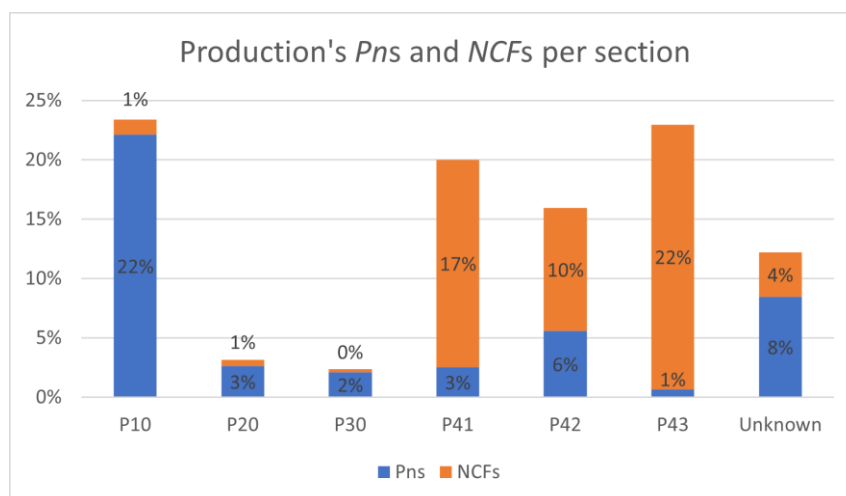


Figure 26: Number of non-conformities (distinction between *Pns* and *NCFs*) per production section, from January 2021 to March 2022.

As the production's critical sections, it was important to understand which are the main causes of the assembly's non-conformities. As so, an analysis was made and is presented in Figure 27, Figure 28 and Figure 29. It is possible to verify that these sections present the same main problem: missing parts or exchange of parts.

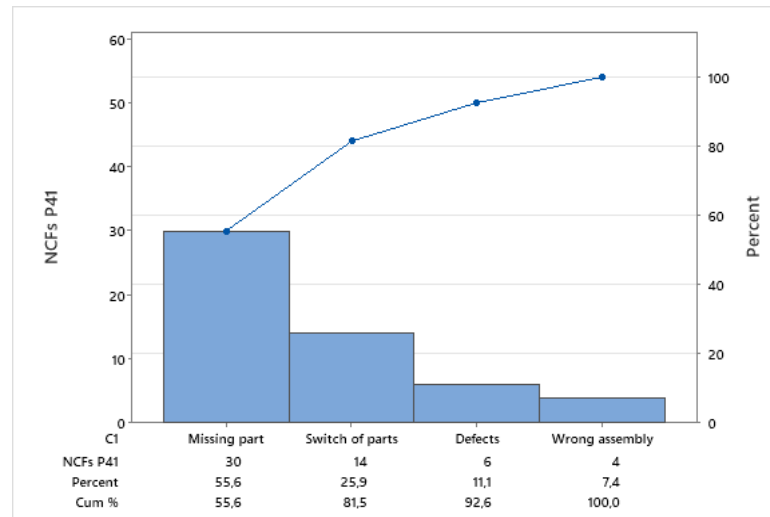


Figure 27: Pareto chart of P41 section *NCFs*.

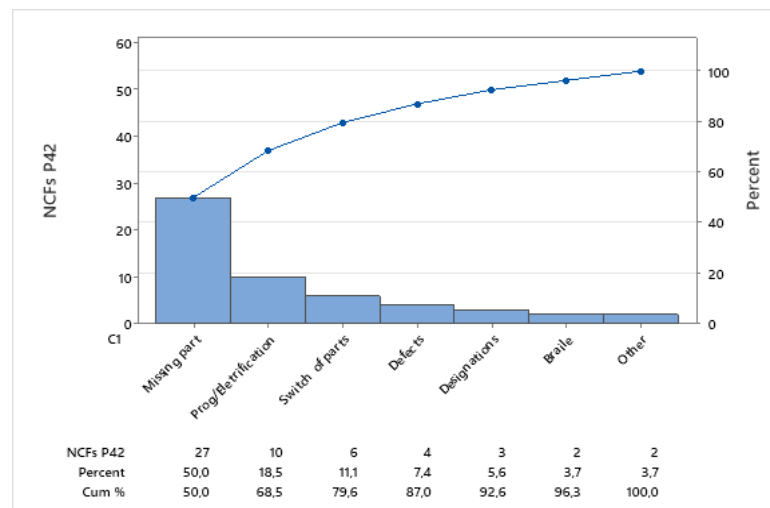


Figure 28: Pareto chart of P42 section *NCFs*.

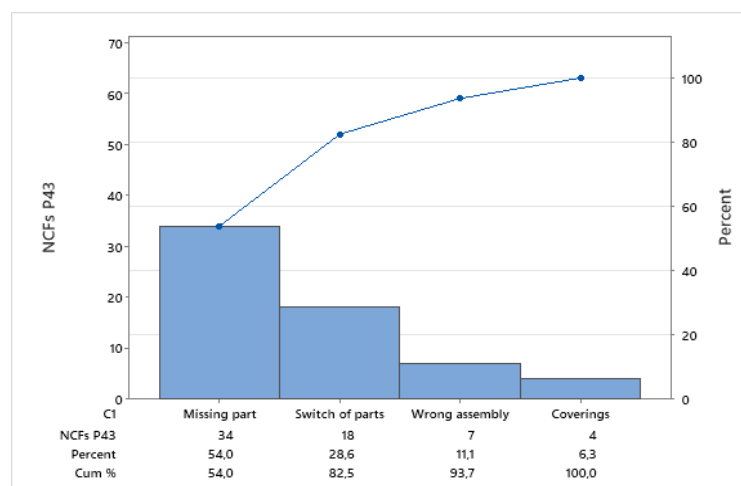


Figure 29: Pareto chart of P43 section *NCFs*.

3.3.3. Relation between non-conformities and elevator type

The possibility of the type of elevator influencing the number of non-conformities was studied. For this analysis, the time horizon of one year (2021) was used.

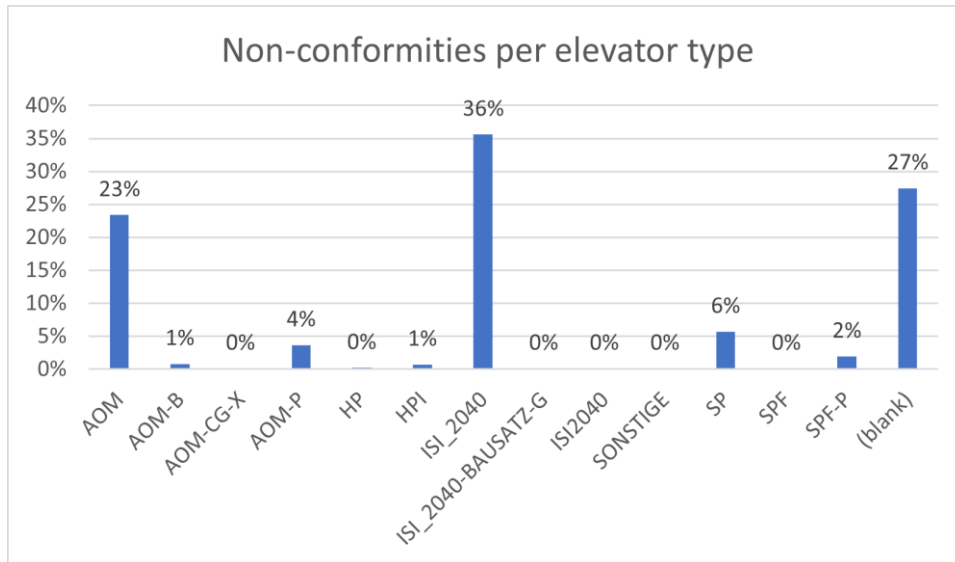


Figure 30: Number of non-conformities per elevator type in 2021.

As it is possible to observe in Figure 30, at least 36% of all the non-conformities happened in an *ISI_2040* elevator model and at least 23% happened in an *AOM* model. It is important to state that these percentages correspond to the minimum values, as there are 27% of non-conformities that are not associated to any elevator type in the ERP *Navision*. Thus, when analysing this data, it might seem that these models are critical. However and in order to confirm or refute this information, an analysis to the produced elevator's type numbers was made. In Figure 31, it is possible to observe the number of produced elevators per type in 2021. When comparing this new data to the previous one, it is possible to state that although these models present the highest number of non-conformities, they are also the most produced ones. Besides this, when calculating the number of non-conformities per elevator produced, it was possible to reach the opposite conclusion of the initial one: *ISI_2040* and *AOM* are the less critical models. The greater the production of one elevator type, the most standardized it will be, which will be translated into a lower number of non-conformities (Table 4).

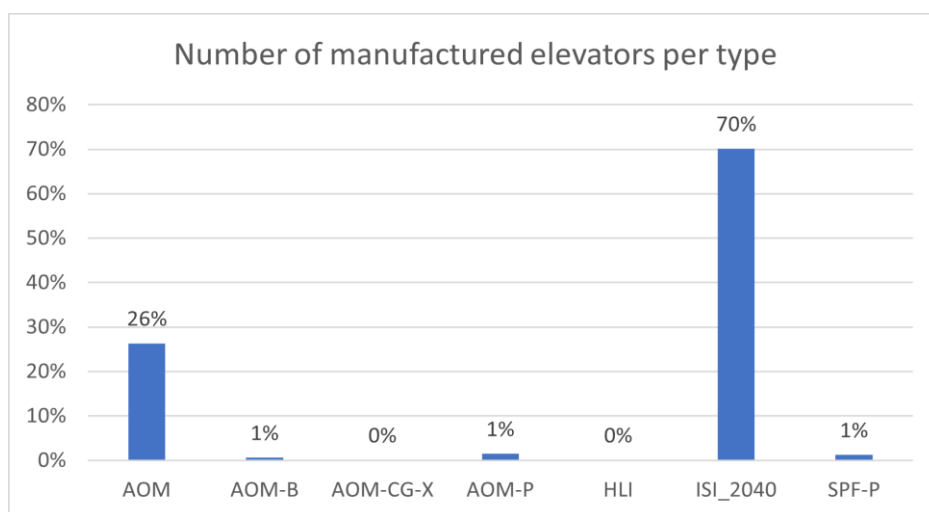


Figure 31: Number of manufactured elevators per elevator type in 2021.

Table 4: Percentage of non-conformities function of the number of produced elevators per elevator model.

Elevator model	Number of non-conformities / Number of produced elevators
ISI_2040 (more standardized)	44%
AOM	77%
AOM_P (less standardized)	212%

3.3.4. Non-Quality Costs

The non-quality costs of the company might be divided into three main categories: rework (extra labour hours); material (scrap and new necessary material); and external costs (related to extra services made regarding the non-conformity, such as service subcontracting). Regarding the non-quality costs, an analysis to the 2021's non-conformities was made.

In Figure 32, it is possible to observe the non-quality costs related to the supply-chain's non-conformities. In Figure 33, the non-quality costs related to the production's non-conformities are presented. In both cases, the most expressive type of cost is the rework one. This happens mainly because of the fact that the actual price of rework per hour is very high (38€/hour).



Figure 32: Non-quality costs of the supply chain in 2021.

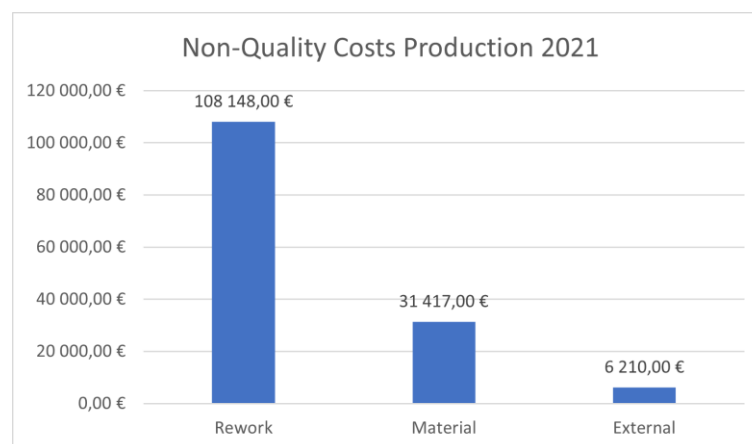


Figure 33: Non-quality costs of the production in 2021.

3.4 Quality control problems: causes analysis

The current quality control issues of the company might be divided into two main categories: problems that are related to the quality controllers' direct work; and the lack of methods, in process and at entrance or at shipping, that might help in the identification of errors (in real time), that would prevent the occurring of non-conformities. Thus, in this subchapter of this report, several problems, as well as its causes, will be stated. Some of them were based on the *MUDA* hunting template, presented in Appendix E.

Considering both quality controllers (S1+ and S2+), during the monitoring of their daily work, it was possible to identify several *MUDA* and problems:

1. Missing working instructions: the current quality control methodology is mainly random and based on the controllers' experience;
2. KPI: the current main KPI is the quantity of controls, that is, the quality controllers are dedicated to completing a certain number of inspections and not to finding the causes of the deviations;
3. MUDA - Duplication of work: firstly, the controller writes down the controlled dimensions and the *Navision* number into a white paper sheet (Figure 34) and only then insert them into the excel file. This happens because of the fact that their registration points are fixed computers installed in fixed places. As so, it is not possible for the controllers to make the registration in the *Excel* file, in real time;
4. MUDA - High percentages of administrative work: to make the registration of a single control in *Excel*, the controllers are taking around 5 and 5,5 minutes for dimensional controls and 2 minutes for visual controls. These values were obtained by *MUDA* hunting procedures: one example for dimensional control registration is presented in Appendix F.

Dimensions	Navision
183453	161505
250	90
24	80
18	30
15	15
11	5,5
10	

Figure 34: Duplication of work in registering the quality controls.

Regarding the S1+ controller, the following *MUDAs* and problems were identified:

1. Only 12,5% of the S1+ controller working hours are dedicated to quality control: S1+ controller has other tasks to do such as registering and preparation of the non-conformities that come from P42 and from the different delegations; or to create *First Sampling Reports* – reports associated to the acceptance of new products, when there is a supplier's exchange;
2. Standardized acceptance sampling method: when controlling the incoming components from the suppliers, the S1+ controller is following the MIL STD 105E norm, but only partially, as he only uses the normal inspection methodology, neglecting both tightened and reduced inspections. Besides this, this standard was discontinued in 1995;

3. MUDA – duplication of work: the person responsible for receiving the suppliers' products at the warehouses is also responsible for verifying each batch in terms of quantity. This means that both this person and the S1+ are verifying the same batches, only with different purposes;
4. MUDA – chemical products registration: as seen before, when a chemical product is supplied, an office member of the QMB department needs to come to the warehouse in order to make the verification of the product. However, this member doesn't make the registration of the product: he sends an e-mail to the S1+ controller and it is the S1+ controller that makes the registration;
5. Drawings consulting: while making a dimensional verification, the S1+ controller needs to consult the technical drawing of the piece in control. However, in order to avoid time wastes associated to the ERP system, the S1+ controller has a folder that contains drawings that might not be the last updated ones;
6. At entrance post-control reacting: when detecting a non-conformity, the S1+ controller might decide if it is worth to continue the inspection of the batch or not. However, this decision is not based on any standard or documentation, it is based on his knowledge and experience;
7. In process quality control: only at the packaging process and always checking the same components;
8. MUDA – at shipping: in the last cell of P42, packaging, the S1+ controller makes several verifications to the final *Kombox* cars. However, there are time wastes related to this inspection, as the S1+ controller loses time in trying to find specific components within the car.

Regarding the S2+ controller, the following *MUDAs* and problems were identified:

1. Only around 25% of the S2+ controller working hours are dedicated to quality control;
2. Available tools that are not used: existence of tools such as micrometres or thickness measurers, but none of them are being used (slow quality control);
3. Quality control of raw materials and chemical products: not existent;
4. MUDA – duplication of quality control of components that come from Schmitt 1: the majority of the components that are supplied to the company are received at *Schmitt 1* and, consequently, controlled at *Schmitt 1*. However, the S2+ controller doesn't know which components have or haven't been verified, so he randomly verifies those components. This means that components might be verified twice;
5. MUDA – hangers' cell: considering the only daily stipulated quality control procedure of the S2+ controller, it was possible to verify a waste of time when searching for hangers that were not verified, as all hangers – verified and not verified ones – are all mixed up in the support;
6. Hangers' cell: despite the 100% inspection, there are still complaints about this component. This happens because, although the quality control procedures, there is no official registration of this quality control.

Considering now the lack of in process controlling strategies, and as seen previously, the quality control objective of the company is completely quantitative as controllers are working to reach a determined number of controls per day, month or year. However, as it is stated by Robinson (1991), "...there isn't much point in inspecting goods at the end of process. Since defects are generated during the process, all you are doing is discovering those defects.", instead of finding ways to prevent those "...from occurring in the first place.". This means that, by having a high number of controls/inspections in the end of the year, it does not

mean that the company is on the way to reduce defects. Thus, it is important to change the actual mind-set and invest on strategies that would prevent those defects of happening.

Regarding the production itself, it was possible to verify, as it was stated in the previous sections, that the assembly sections are the most critical ones in terms of *NCFs*. As for *Pns*, the most critical section is P10. Thus, these should be the sections in which there would be a higher quality investment. Nevertheless, the implementation of quality control methods and strategies to all the other sections might also be studied.

4 Proposed improvements and solutions

Once the identification and the analysis of the main encountered problems was finished, it was necessary to think about feasible solutions to respond to them. In the beginning of this chapter, the KPIs that evaluate the results of the purposed improvements/solutions are presented. Then, those improvements/solutions are described. It is important to note that it was not possible to implement all of the stated improvements/solutions, however, for each one of them, the expected results are defined.

4.1 KPIs definition and objectives

Within the project's context and after the statement of various problems regarding the actual quality control system of the company, it was necessary to establish quantifiable objectives. To do this, two different KPIs were defined.

The first KPI (equation 4.1) quantifies the non-quality costs of the company, function of the production's invoice volume. It is important to state that the considered non-quality costs must be only the ones associated to the production (in-process non-conformities) and to the supply chain (incoming products non-conformities).

$$KPI_1 = \frac{\text{Non quality costs (Supply Chain and Production responsibility)}}{\text{Production's invoice volume}} \quad (4.1)$$

The second KPI (equation 4.2) quantifies the number of non-conformities per section of the company. The sections that are within the scope of the project will, once again, be the incoming of products at the warehouse and the in-process sections (P10, P20, P30, P41, P42 and P43).

$$KPI_2 = \frac{\text{Number of nonconformities}}{\text{Section}} \quad (4.2)$$

For both KPIs, the established objective was to reduce both in, at least, 20%.

It is important to enhance that another objective of this project was to reduce the number of controllers to one, freeing up the other for other types of work within the company. As so, all calculations made in this chapter considered only the working hours of one single operator.

4.2 Incoming quality control: Implementation of a new acceptance sampling standard

In this section of the report, the purposed improvements for the incoming quality control process are presented.

As confirmed in the previous chapter, it was necessary to establish a new quality control acceptance sampling plan at the products' incoming from the suppliers. In order to do this, the objective was not only to introduce ISO 2859-1 (the closest to the one that was being

used already by the company), but also to integrate it with ISO 2859-3. This integration of standards would allow the replacement of a static quality control process with a dynamic one, in which the history on the product itself and on the supplier would help not only to determine the sample to be inspected but also the frequency of inspection of batches.

The flowchart of the new acceptance sampling plan to be applied is presented in Appendix G. Considering the Skip-by-Lot sampling plan, the flowchart of frequencies is presented in Appendix H.

In order to implement the new sampling plan, the objective was to create a *Visual Basic for Applications* (VBA) program which would assist the quality controller in the following parameters:

1. When inserting the article number of the incoming batch, the program would, automatically, verify the current inspection plan of the product and, consequently, indicate the necessity of verifying that specific batch or not;
2. If the verification of the batch is necessary, the quality controller must insert the batch dimension. By inserting this number, the program would automatically give him the sample number to inspect;
3. Once the inspection is made, the quality controller would insert the number of non-conformities found within the verified batch. By doing this, the program would automatically accept or reject the batch, informing the quality controller;
4. Finally, by rejecting or accepting the inspected batch, the program would automatically change the inspection plan if conditions to change are verified.

In Figure 35, it is possible to observe the user interface created for the incoming quality control, in which all of the previous parameters are met. In this example, the inspected product is in *Skip-Lot* sampling and the incoming batch does not need to be verified: this is why the textboxes associated with the batch dimension, the sample and the acceptance numbers and the number of deviations found are blocked. In Appendix I, it is possible to observe the code used for the creation of this user form. The final future objective regarding this interface is to connect it with code readers, that would automatically read the code of the incoming product, without the need for the controller to insert the name of the supplier and the article number.

The screenshot shows a VBA user interface for incoming quality control. It features several input fields and buttons. The 'Fornecedor' field is a dropdown menu. The 'Nº de obra / Cód. artigo' field contains the value '383846'. The 'Plano inspeção atual' field contains 'SL'. The 'Verificar este lote?' field has a 'Não' button. The 'Frequência verificação' field contains '1 em 3'. The 'Dimensão do lote', 'Amostra a controlar', 'Número aceitação', and 'NCFs verificadas' fields are blocked. The 'Plano inspeção pós controle' field contains 'SL'. There are 'Enter', 'Registrar Controle', and 'Atualizar' buttons. The logo 'S+ SCHMITT+SOHN ELEVADORES' is in the top right corner.

Figure 35: User VBA interface for the incoming quality control.

After the implementation of the new sampling plan and the new VBA application, several advantages are expected:

1. Time devoted to quality control is directed to products/suppliers that are historically more critical;
2. Reducing of the time controlling incoming products: products that have a good history will be less inspected comparing to the current inspecting procedures;
3. 100% elimination of the time spent consulting information in paper sheet tables.

The daily time that should be spent in the incoming of products inspection will be defined in the next section of this chapter, as it was not possible to define it without also considering the other forms of quality control.

4.3 In process quality control

Regarding the in process quality control, the main objective was to create standardized plans for the controllers' daily work, with the aim that inspections should no longer be based solely on the experience of the controllers and on responding to on-time detected deviations on the shop floor, but rather based on real historic data, namely the history of non-conformities. As so, the creation of a Quality Control System for the in process procedures was based on three different steps: firstly, the obtention of the input data that is stored in the ERP system, *Navision*; secondly, the handling and processing of the obtained data; and finally, the establishment of standardized procedures for the quality controls. The summary diagram of the basic architecture of the target Quality Control System is presented in Figure 36.



Figure 36: Basis of the TO BE in process Quality Control System.

4.3.1. Obtaining input data

As it was previously stated, the company has an ERP system that enables the storage and the flow of data between its several departments. In order to obtain the necessary input information, it was necessary to export the relevant data from the ERP system. To do this, a SQL routine was created and, after that, it was transformed into a VBA code that, through pressing a *Macro* button, imports the data to *Microsoft Excel*. It is possible to observe the VBA code in Appendix J.

4.3.2. Data processing

After the relevant data has been sorted into a *Microsoft Excel* sheet, it was necessary to treat and process it, aiming to use the information obtained in the smartest possible way. For this, *Microsoft Power BI* software was used. The main purpose of using this software was to build dashboards that would relate and resume the data in an efficient way, allowing the

QMB director to, weekly, present a non-conformities analysis to his team and to orient both quality controllers, by giving them daily working plans. This would allow quality control to no longer be based entirely on the controller's experience or on the reaction after detection of deviations, but rather on the history of non-conformities. Thus, the dashboards would correspond to the decision/orientation tool of the proposed Quality Control System. In Appendix K, the relational model used for the dashboards' creation is presented.

Production Dashboard

In Figure 37, it is possible to observe the main built dashboard for the production.

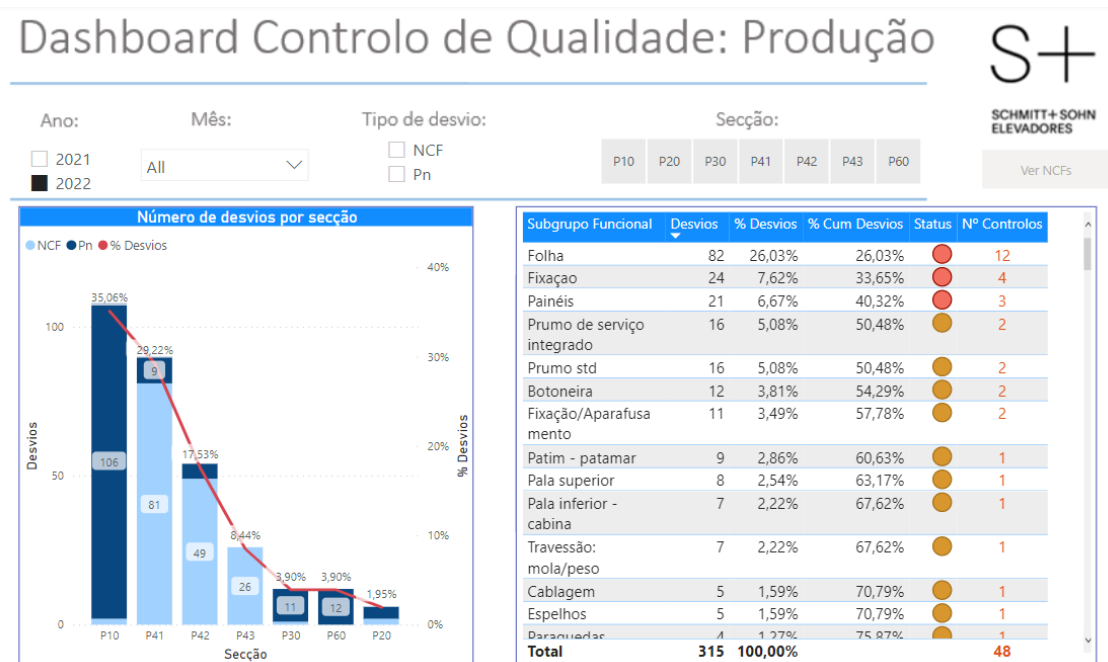


Figure 37: Production dashboard.

Below the main title, four different *slicers* were inserted for the user to be able to filter the information by year, month, type of deviation (*Pn/NCF*) and/or causative section. Note that P60 was introduced in this dashboard due to future needs of the company, but it is considered to be outside the scope of this dissertation.

The information regarding the production's non-conformities was divided into two different visual elements: on the left, a bar chart, that presents the number of non-conformities per section, making the distinction between *Pns* and *NCFs*; and on the right, the decision table.

The decision table presents the information by elevator functional subgroup, a parameter that was considered as the primary decision parameter, due to the level of specificity it brings: the functional group was considered to give too general information, while the *Navision* article number was considered to be too specific. For each functional subgroup, the number, the percentage and the cumulative percentage of deviations is presented. A *Status* column was created, based on the ABC classification, considering the cumulative percentage value:

1. From 0 to 50% - red light: critical functional subgroups, mandatory controls;
2. From 50 to 80% - yellow light: medium criticality functional subgroups, recommended controls;
3. From 80 to 100% - green light: noncritical functional subgroups, no controls.

Finally, the last column corresponds to the calculation of the daily number of controls. In order to determine it, it was considered that, from the 8 daily theoretical working hours, an employee is working 7, due to the realization of small breaks along the day. From the available 7 hours, it was stipulated, after a root causes analysis, that around 85% of the time spent in inspections (6 hours) should be dedicated to in-process control and only around 15% (1 hour) to incoming control. Besides this, after the realization of some trials with the quality controllers using a new registering tool, an average was made and it was determined a mean value of 7,5 minutes per control. Thus, the number of daily controls per functional subgroup was calculated using Equation 4.3.

$$\text{Number of inspections} = \frac{\% \text{ deviations} * 6 * 60}{7,5} \quad (4.3)$$

In addition to this, below the company's logo, a *drill-through* button was inserted, which, when activated, takes the user to an auxiliary page (Figure 38) that displays the non-conformities and their respective descriptions, the detailed description of the items associated with the deviation and its causes, keeping all the filters applied on the dashboard's main page.

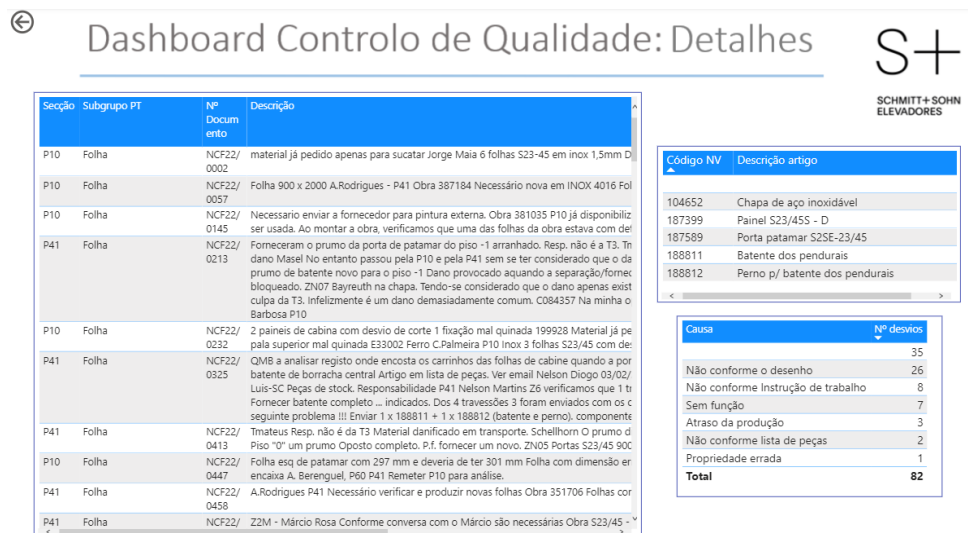


Figure 38: Auxiliary production dashboard.

While doing the data treatment, it was possible to notice that the parameter associated with the deviations' causes, the error subtype, was not properly standardised in the company's ERP system. Situations such as the existence of two deviations with the same cause, but that in the system have different causes due to spelling errors are common, other than the fact that there are too many possible specific causes for the deviations. As so, a proposal was made to change the parameters defined in *Navision*, to eliminate all duplicate causes and retain only those that are more general, through a process of standardisation of causes. In the end of this analysis, it was stipulated that the final error subtypes, associated with the production, should be:

1. Not according to the preparation;
2. Damaged;
3. Missing;
4. Exchanged;
5. Functionless.

This new causes categorization would permit a better data treatment and, consequently, an easier clarification of the problems and errors that happen within the company's shop floor.

After the control dashboard was complete, the need to access deviations in a more macro way was verified, with a view to a more management-level analysis. As so, another dashboard for production was created, presented in Figure 39, constituted by six visual elements:

1. One KPI that is counting the number of non-conformities since the beginning of the current year and that compares this value with the established objective for the year;
2. Two cards, one in red that informs which is the section with the higher number of NCFs and one in green that informs which is the section with the lowest value;
3. One scatter chart that shows the evolution of the number of non-conformities since the beginning of the current year per month;
4. Two donut charts that present the top 5 of functional group and functional subgroup components with higher number of deviations.

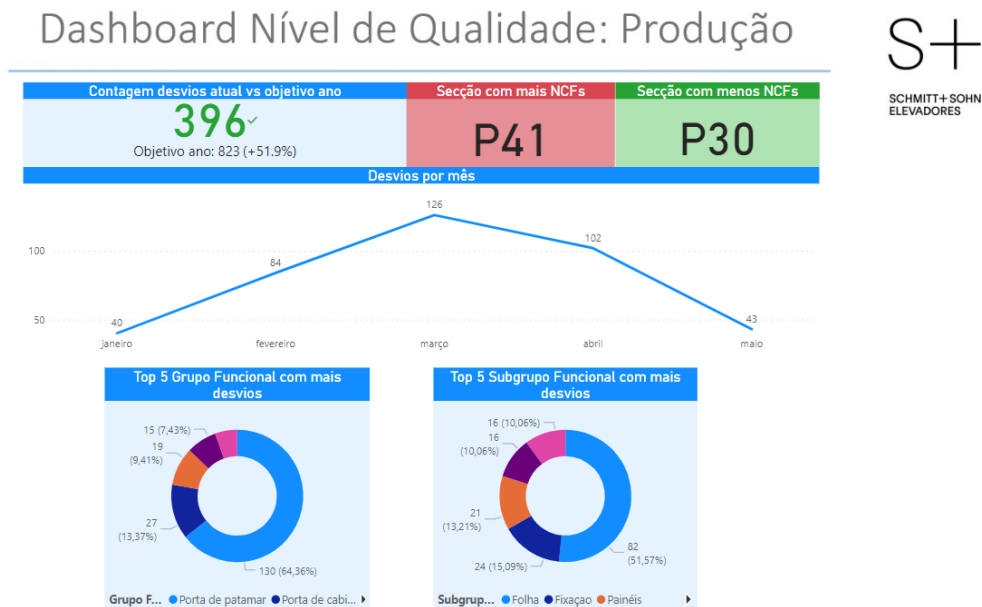


Figure 39: Production dashboard for management-level analysis.

In order to keep the dashboards created always up to date, it is necessary to update the *Macro* created in VBA weekly. To ensure that this process is carried out, as well as to facilitate the interpretation of the main control dashboard, a work instruction (IT) was created, where each of the steps are explained in detail (Appendix L).

Supply Chain

As it was stated previously, the daily control time established for the incoming products from the supply chain is one hour, that corresponds only to around 15% of a labour day. This value was determined after a root causes analysis: to focus on the in process controls would translate into better final results; regarding the suppliers, it was established that supplier control reports would become mandatory if and when justified.

As an auxiliary tool of the created *Microsoft Excel* VBA application for the incoming products, a dashboard was also built for the supply chain (Figure 40).

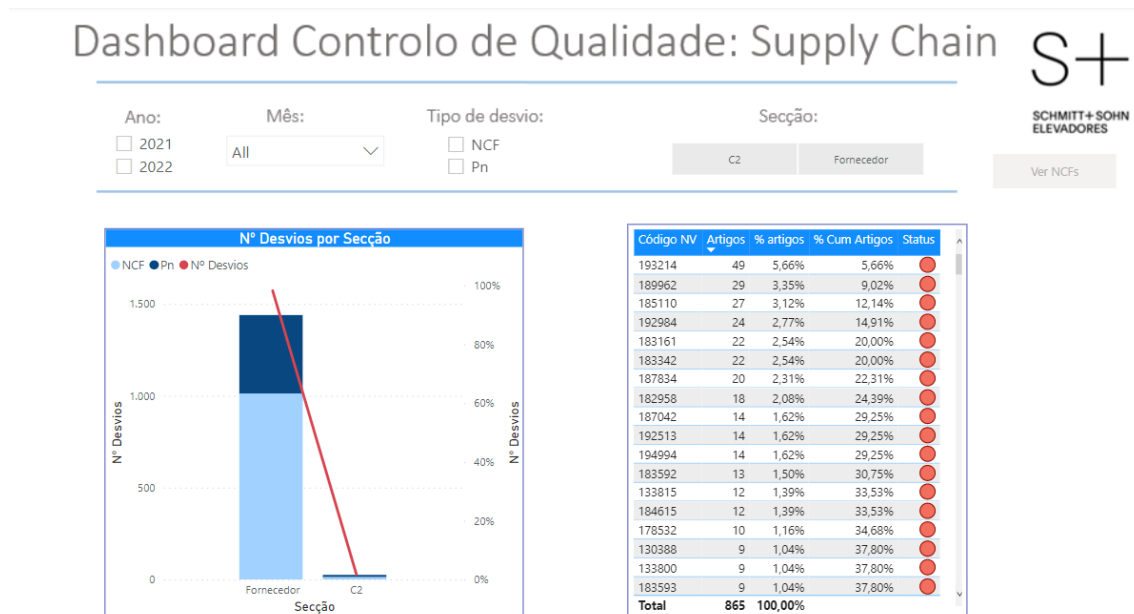


Figure 40: Supply Chain dashboard.

This dashboard is similar to the one made for the production, however, in this case, the decision table presents the information by the *Navision* article number. This would facilitate the incoming control, as each one of the batches that enter the different warehouses are all labelled with this code number. Also differently from the production's dashboard, the supply chain's dashboard does not indicate the number of daily inspections that should be made: this number is provided by the created VBA application. As so, this dashboard works as a visual presentation of the most critical components that are entering the company.

4.3.3. Data output

After the data was processed and treated in *Microsoft Power BI* and the daily quality control plan was established, it was important to define how the controls should be made, not only by the definition of the different steps associated to each control, but also to provide to the controller a tool that would make the controls and their registering more efficient.

Quality controls standardization

In the previous section, the daily quality control plan was established in terms of quantities and frequencies. However, it would be important to define the steps associated with each one of the different controls, guiding the controller on how to inspect specific components. As so, meetings with the different production sections' team leaders and section chiefs were handled, aiming to stipulate the aspects and parameters that should be inspected, by problems identification, root causes analysis and the definition of action plans. As an example, in Appendix M it is possible to consult the result of the meetings with the P42 leaders. Once these meetings were completed, it was possible to create standardized ITs. In Appendix N it is possible to observe an example of a created IT.

Control tool

As seen in the previous chapter, when the quality controllers inspected a specific part, they would write down the elevator number on a white sheet of paper so that later, at the end of that working day or at the beginning of the next, they could record all the checks made in *Microsoft Excel*. They would also need to transfer all the photos taken that day from the camera to the computer, which was an action without any added value.

Thus, another of the main objectives within the data output was to give to the controller a tool in which the quality inspections would be carried out in real time. Firstly, a mobile device (tablet) was given to the controller, so that the registrations of the controls were no longer made in a fixed place (controller's office) but could be made at the location of the control itself.

Then, a new widget for the control registration was implemented: *iAuditor* (Figure 41).



Figure 41: *iAuditor* platform logo.

This platform allows the creation of forms with checklists, in which the inspection procedures, defined by the following of the ITs previously mentioned, are presented step-by-step: the controller follows the procedures and, to each parameter of the control list, he only needs to check if that parameter is ok or not. Another valuable tool enabled by this platform is the direct association of pictures to each one of the control parameters. In the end of the inspection, the quality controller signs the form and, automatically, a *pdf* report of the finished control is generated. In Appendix O, it is possible to observe an example of a completed generated report.

The implementation of this platform allowed the complete elimination of the administrative time spent in registering the controls into *Microsoft Excel* and in transferring photos from the camera to the computer. Besides this, it eliminates the duplication of work regarding the writing of the elevator number in the white sheets of paper. It also allows the inspections and their registrations to be made in real time (Figure 42). Following the example of Figure 42, before, the full control of a KTV Coupler took around 6 minutes (considering the total time spent regarding this component: control, movements on the shop floor, registration in *Excel* and transferring of pictures from the camera to the computer); now, the full control of this component is taking around 5 minutes. Thus, it is possible to state that there was a time reduction of 17%, that was accompanied with other advantages, such as the automatic generation of a complete report, as well as the reduction of error probability, since the registration is done in real time.

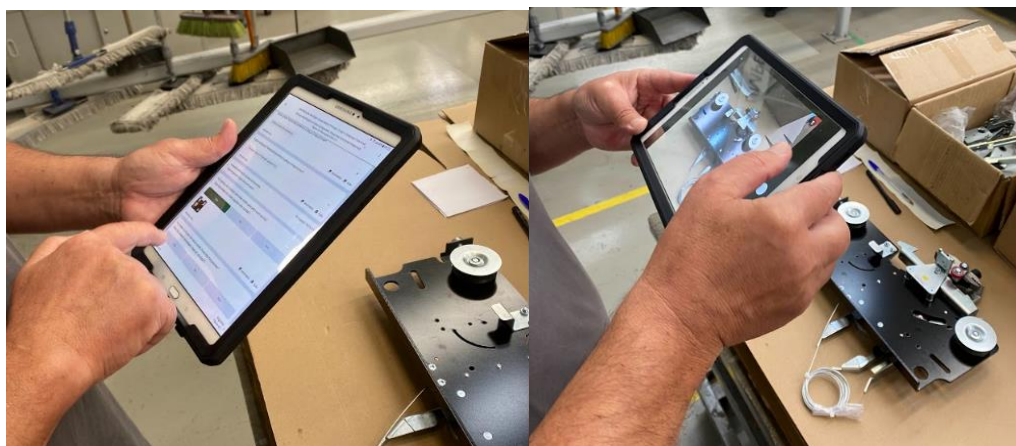


Figure 42: Right: Quality control registration in real time; Left: Association of pictures to the control registration.

As so, the in process Quality Control System is complete, being summarized in Figure 43.

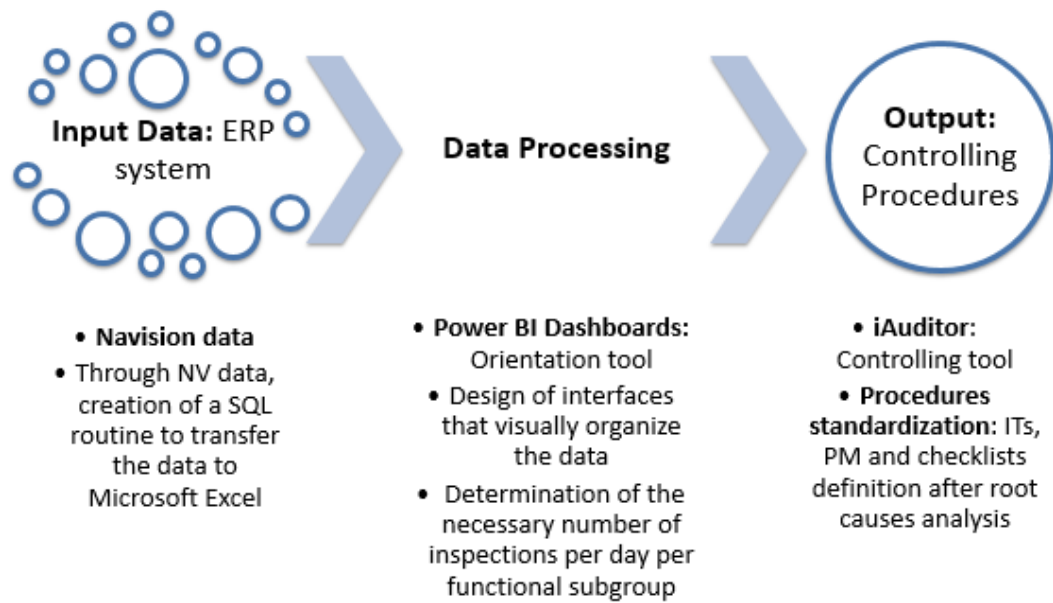


Figure 43: TO BE in process Quality Control System.

4.3.4. Reaction after rejected component

Still within in process control, when a non-conformity was detected in the shop floor of the company, the quality controller would react with the placing of a “blocking” label (Figure 44).

BLOQUEADO	
IDENTIFICADOR / COMPONENTE / N.º IDENT.	QUANTIDADE BLOQUEADA
REGRÃO IDENTIFICAD.	#NECEDOR
REGRÃO DESEJO	
SOLUÇÃO: WCF 22 / 1879	
REGRÃO	Quantidade
DATA:	DATA:
ASS:	ASS:

Figure 44: Blocking label.

In this label, they would have to fulfill some fields about the non-conformity itself, such as the elevator’s number, the description of the component, the blocked quantity, etc. However, there were some problems regarding this procedure:

1. This same label is used in other cases of the shop floor, for example, when a trolley car is not yet ready to go to the next section for missing parts or when there are excess of production parts. Thus, this enables operators to go and pick up a non-compliant piece;
2. Although the registration of the non-conformity is made in the ERP *Navision*, the decision about what happens to the non-conforming components might take an indefinite period of time.

As so, the idea of creating two new labels arise, one for non-conforming components that are still possible to rework (Figure 45 - right) and other to non-conforming components that are not possible to rework and that must go directly to the scrap containers (Figure 45 - left).

MATERIAL PARA SUCATAR		MATERIAL PARA REWORK	
Nº Obra:	Quantidade:	Nº Obra:	Quantidade:
Componente:	Seção:	Componente:	Seção:
		Descrição do defeito:	
		Solução:	
Data:	Bloqueado	Nº NCF:	
Ass:		Ass:	

Figure 45: New classification labels for deviations in process.

This solution brings several advantages:

1. It prevents the operators to confound non-conforming products from conforming products that are blocked due to other situations, preventing, consequently, the non-conforming parts to be wrongly picked, assembled and sent to the delegations;
2. It requires a decision to be taken immediately on what happens to the non-conforming products;
3. It allows the ecopoint operator to visually know immediately the products that must be taken to the scrap containers.

After the decision on what happens to the non-conforming products is made, the *Pn* must be registered into the ERP system, entering directly into the quality circle of the causative section. Once in the quality circle, the non-conformities work as the input to weekly brainstorming meetings, in which the teams work on analysing the deviations causes and on finding solutions, by filling out 8D reports (Appendix P). As the output of these meetings, new controlling procedures might be established, that will be implemented in *iAuditor* checklists; or, on the other hand, there might be the creation of *Poka-Yoke* systems that would act directly on the encountered causes. In Figure 46, it is possible to observe the purposed flowchart for the reaction to a non-conformity detection within the company's shop floor.

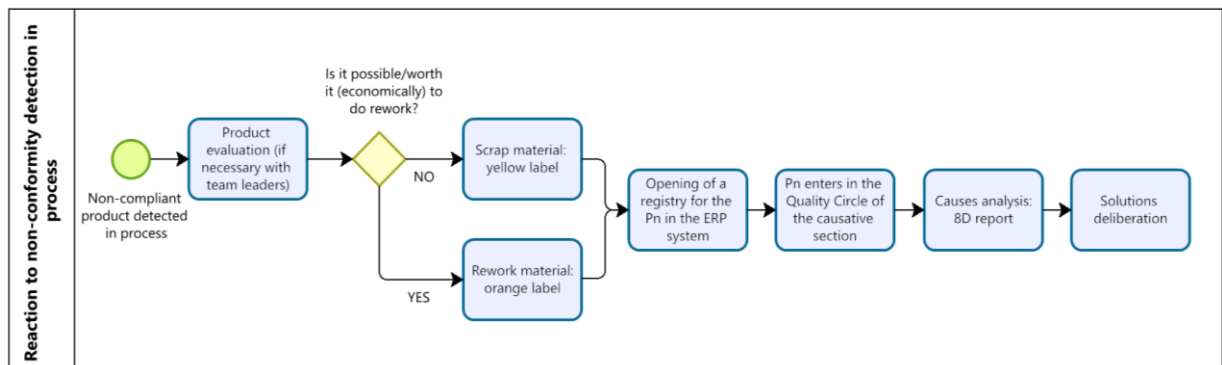


Figure 46: Reaction to a in process deviation flowchart.

Ideally, the shop-floor should have a non-conforming products' area. However, due to the current lack of space, the non-conforming components must be sent directly to the rework/scrap section.

Creation of *Poka-Yoke* systems

As it was stated before, one of the possible outputs of the quality circles are the *Poka-Yoke* systems. In this section of the report, some suggestions of mistake-proofing systems are presented.

Avoiding left/right parts since their development

One of the most common shop floor's non-conformities is the trade of parts, which happens due to several causes. One of the main ones is the existence of many pairs of parts that have the same function and that visually are very similar, but that are symmetrical to each other. This happens because one is applied to the left side of the elevator and the other one is applied to the right side of the elevator. This type of configuration makes these parts very easy to confound, which results in the delivery of right parts when what was needed were lefts ones or the opposite.

Thus, an analysis to some of the left/right pairs of parts was made, aiming to understand if it would be possible to transform them into a unique part, that would be able to be used for both situations, that is, for left or for right applications. This type of thinking might be considered as part of the mistake-proofing/*Poka-Yoke Lean* systems, as they would prevent trade errors to happen since the development of the product itself.

In Figure 47, two different pairs of left/right parts are presented, both used in the assembly of doors. In both cases, it would only be necessary to add some holes or grooves to make them work for both applications. However, an analysis of the internal forces of each piece should be made in order to understand the feasibility of the transformation. It is important to state that as these two examples, many others of the same type might would have been presented.

It is expected that this modification would result in the total elimination of trade part mistakes related to these pieces, which would reduce the non-quality costs of the company in terms of rework. This modification would also bring other advantages, such as reducing the number of the SKUs of the company, that would translate into an easier production planning and also into an easier picking through the shop floor.



Figure 47: Examples of pairs of left/right parts that would easily be transformed into a unique part.

Labelling the sills

While doing a root cause analysis about the main non-conformity type of the shop floor of the company – missing parts – it was possible to understand that around 10% of the missing parts of P41 section (the highest value) was related to the sills. In this way, an analysis was carried out in order to try to understand what problem was being the basis for such a high number of deviations.

After the analysis, it was possible to understand that there are two types of sills: one for the common doors, that must be tightened with specific pins (Figure 48 - left); and other for the doors associated with the service upright, that do not need the specific pins (Figure 48 - right).



Figure 48: Two types of assembled sills.

To distinguish both sills, there is only a small label with the batch number of the sills associated to the service upright (Figure 49), that can easily lead to picking errors by the packing operators.



Figure 49: Current sill distinguishing label.

As so, a more visual label is suggested (Figure 50), similar to the ones that are already being used in this section as mistake-proofing systems. Through this label, the operators would know exactly the sills that are associated to the service upright, which would make picking errors much more difficult to occur: it is expected that with their implementation the missing pins deviations would be completely eliminated.



Figure 50: Proposed label for sills associated with the service upright.

4.4 Before expedition quality control

Taking into consideration the ideals of the TPS philosophy, the approach of controlling the final product is considered to be too late within the production chain: if a deviation is detected only before the expedition of the final product, it is likely that all the other products in this batch have the same defect, which would lead to overly high rework costs. Moreover, inspections of the final product could result in delivery delays. As so, it was defined that the before expedition quality control at the *Schmitt Elevadores* shop floor would be divided into two different types of controls.

The first one is, effectively, an at dispatch control, not to the final product, but to the state of its packaging. The quality controller would move to the expedition area of the shop floor and inspect the following parameters:

1. State of the wood of the pallets;
2. State of the cardboard boxes;
3. Ensure that the packages are correctly labelled;
4. Ensure that the packaging IT has been followed.

On the other hand, it would also make sense to analyse the final product, mainly due to the constant exchanges and shortages of components that are verified by the delegations. However, instead of doing it in the end of the production processes, this verification would be made during the last process of the shop floor of the company: the packing. Thus, it was determined that, once a week, the quality controller would inspect the packages of a certain functional main group: each week of one month would correspond to one functional main group (Doors, Command, Car or Shaft Equipment), being that the controller would verify the following parameters:

1. Exchanges and shortages of components;
2. The stowage of the components;
3. State of the components.

Once the design of the *Schmitt Elevadores'* Quality Control System with regard to the control in the incoming of components, during the processes and before expedition, was completed, it was possible to fill in the matrix previously presented in the objectives of this dissertation. This matrix is presented in Figure 51.

Methods/Tools	Who?	Periodicity?	Trigger?	How? (Description/Standard)
Excel new interface: incoming components control (integration of standards ISO 2859-1 and ISO 2859-3)	QMB warehouses controller	Daily: 8 controls/day (1 h/day)	Incoming components from the suppliers	-Microsoft Excel -ISO 2859-1 and ISO 2859-3
Obtaining Input Data: Transferring data from ERP Navision to Excel	QMB Leader	Weekly updates	Weekly update	-SQL Routine
Controlling Dashboards (Supply Chain and Production): Data Processing	QMB leader, quality controllers, Production	Weekly updates	"Good morning" meetings Operations Meetings Daily control plans consultation	-Microsoft Power BI
Output Data: Work Standardization	QMB department	Result of Quality Circles/8D reports	Quality Circles and 8D reports New processes, materials or machines	-ITs and Process Mappings
Output Data: iAuditor	QMB department	Daily: 48 controls in process/day (6h/day) + Weekly: 1 control to a functional main group before expedition/week+ Inserting new checklists	Carrying out controls Quality Circles and 8D reports	-Tablet with access to the app
Output Data: Poka-Yoke systems setting up	QMB and Production departments	Result of Quality Circles/8D reports	Quality Circles and 8D reports	-Causes Analysis -Brainstorming

Figure 51: Final Quality Control System matrix.

In addition, three process mappings, one for each control sector (incoming products, in-process and before expedition), were created in order to document the quality control processes of the company. These process mappings are presented in Appendix Q, Appendix R and Appendix S.

Considering the KPIs defined at the beginning of this chapter, it was not possible to draw any conclusions about them. This is due to the fact that there was not enough time to analyse them after the implementation of the new Quality Control System. It is expected that from now on, with the direction of the controls based on the non-conformities' history, the number of deviations tends to decrease, being defined a new analysis of the KPIs in a time frame of 6 months. Therefore, the current results of the implementation of this system are presented in terms of efficiency, regarding the reduction of time spent with each control and the elimination of several *MUDAs*.

5 Conclusions and future work perspectives

Large industrial companies, such as *Schmitt Elevadores*, are constantly under a big competitive pressure not only among their competitors, but also concerning their clients quality specifications. Thus, it is important to have a Quality Control System, that allows the reduction of a maximum of actions with no added value, that is, that directs quality controls towards those components that are most critical within the company.

As so, the main challenge of this project was to design a Quality Control System for the three control stages required within the company: the incoming of products, the production shop floor processes and the before expedition final control.

Considering the incoming of products, two new acceptance sampling standards, ISO 2859-1 and ISO 2859-3, were integrated and implemented, aiming to direct controls towards the most critical parts and allowing a direct entry of those that never presented problems in the past. This implementation replaced the tables printed on paper (and the time wasted in their consultation) with a new VBA interface that through the insertion of the article code directly informs the user if that batch needs checking or not, while before all batches were controlled. If the batch requires inspection, by entering the batch quantity, the interface directly informs the sample to be inspected. Then, the user inserts the number of deviations found within the batch and the program automatically defines if the batch is compliant or not, with a continuous update of the product inspection mode.

Regarding the shop floor production processes, the historical data that is stored in the company's ERP is now used to define daily controls plans for the quality controller. For this, it was necessary to obtain the input data from *Navision*, by using an SQL routine. Once the required data is available on *Microsoft Excel*, it is imported weekly to *Microsoft Power BI*, where it is treated and presented in a visual way, that allows the definition of daily control plans, in terms of what to control and the quantities to control. Finally, concerning the controls themselves and aiming to define how these should be made, procedures with the objective of work standardization were made, through the root causes analysis of the historical deviations of each section. As so, it was possible to document ITs and Process Mappings for the control of several components of the shop floor. These ITs were then applied through the implementation of a new software tool, *iAuditor*, that when installed in a mobile device guides the quality controller step by step and allows in real time registration of inspections.

At last, the before expedition quality control of the final product was considered to be a non added value activity, by following the TPS philosophy. Therefore, it was determined that the final product would be lastly inspected still during the process, more precisely at the moment of packaging, in which the stowage of the final product, as well as the lack and exchange of parts would be controlled. Before shipment, the condition of the packaging is inspected, not the final product.

With the implementation of the new Quality Control System it was possible to direct the quality controls in the smartest possible way, based on historical data, avoiding the

random control that used to be done based only on the experience of the controllers. It was also possible to avoid several *MUDAs*, such as the time spent on registering the controls in the computer, as well as to eliminate all the duplications of work that were made to point out the article/elevator number in white sheets of paper. The time spent in transferring pictures from the camera to the computer was also eliminated. In a real example of the shop floor, the control time was reduced in 17%, besides the fact that now the control registrations are made in real time, which reduces the probability of registration errors and the fact that together with the control, there is the automatic generation of control reports.

Besides the design of the new Quality Control System of the company, other suggestions were made, mainly due to the problems that were associated with the reaction after a deviation was found in the shop floor and also with respect to the creation of new mistake-proofing systems, aiming the reduction of errors throughout the production.

Considering the future work perspectives, the main objective would be to reduce the number of controls of the final product, replacing them with mistake-proofing systems and, consequently, by implementing controls to the *Poka-Yoke* systems themselves.

One of the possible approaches regarding the anti-error systems would be the investment in the automatization of the shop floor, with a view in applying the *Industry 4.0* paradigm. On the one hand, the implementation of *pick-by-light* systems in the work benches with *Kanban* boxes (border line) should be considered, due to the in-time guidance given to the operators: this guidance would allow the picking of the right parts in the right quantity, leading to the decrease of both missing and trading of parts deviations, that, as it was seen, correspond to the most common cause of deviations within the company's shop floor. On the other hand, the implementation of a RFID system with labels should also be considered, aiming to reduce the missing parts deviations. The idea would be to have RFID readers in the end of the packing roller conveyors of P41 and P43 and in the final *Kombox* of P42, that would read the labels of the components and, through an association to the elevator's parts list, would alert the operators if some part was missing or exchanged. This solution would present some obstacles, as a standard elevator consists of around 20000 components. As so, the idea would be to label specific groups of assembled components.

It is important to enhance that, as indicated in the name, the continuous improvement of processes never stops. Thus, continuing to update all the work that has been done is essential for its future success, as new problems and new ways of optimising processes are constantly emerging.

To conclude, this project was a very enriching experience in that it was possible to apply theoretical knowledge in a real industrial environment, together with a team that promoted the learning process and the motivation throughout its duration.

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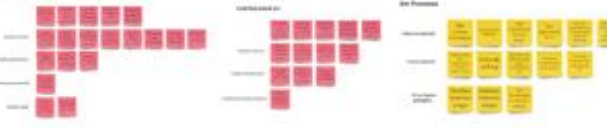
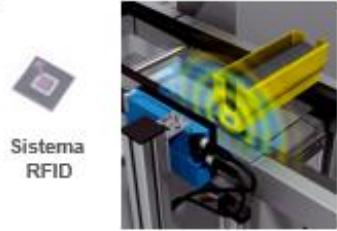
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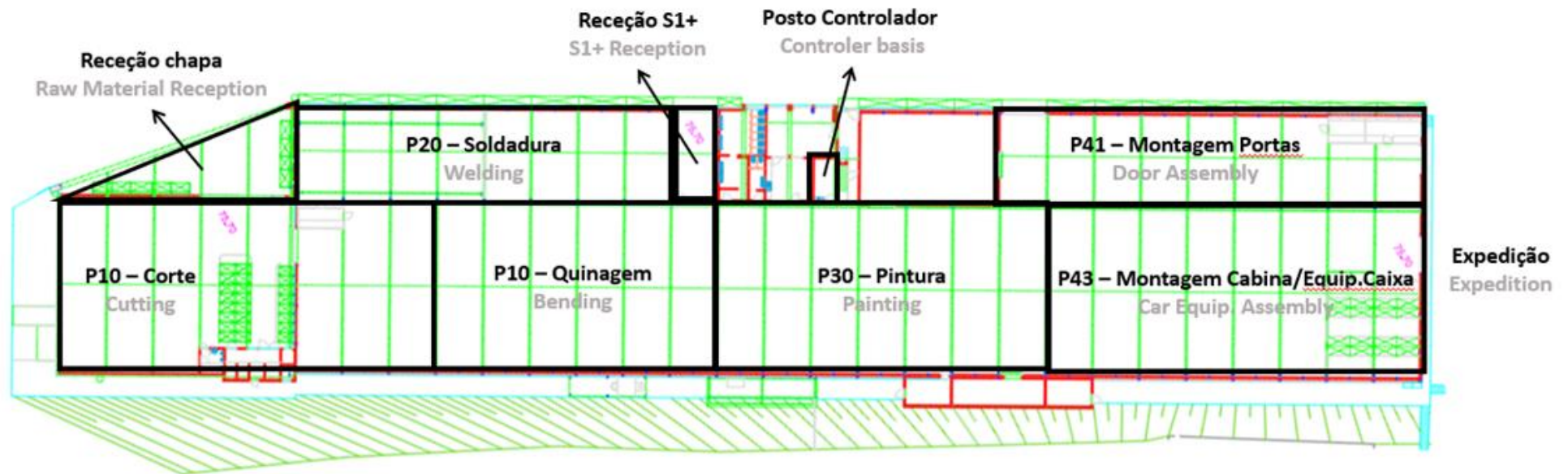
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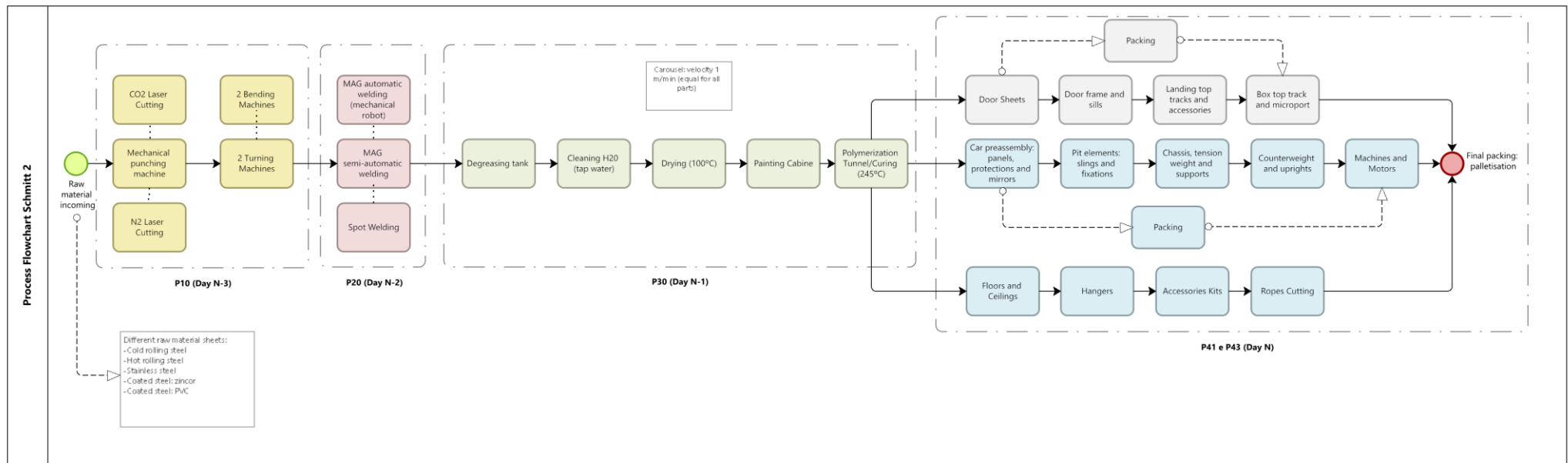
APPENDIX A: Project's A3 Report

A3	Projeto: Melhoria do Sistema de Controlo de Qualidade Departamento: QMB	Data início: 02-03-2022 Data prevista fim: 01-07-2022 						
1. DEFINIÇÃO DO PROBLEMA 	4. ANÁLISE DA CAUSA RAIZ DO PROBLEMA 	7. PLANO DE AÇÕES 						
2. ESTADO INICIAL 	5. DESENHO DE SOLUÇÕES  Dados Navision Através dos dados NV, criação de uma rotina SQL para passar data para Excel. Dashboard Power BI ferramenta de orientação Realização de dashboards que organizam data visualmente Indicação de número de controlos necessário por subgrupo funcional IAuditor ferramenta de controlo Standardização procedimentos: criação de ITs, PM e checklists na ferramenta após correta análise de causas	8. RESULTADOS OBTIDOS - Eliminação tempo gasto em trabalho administrativo pelos controladores; - Eliminação da duplicação de trabalho na escrita em folhas brancas; - Registo de controlos em tempo real e no local do controlo; - Controlos baseados no histórico dos desvios.						
3. OBJETIVOS <table border="1" data-bbox="392 1109 750 1316"> <thead> <tr> <th>KPI</th> <th>Objetivo</th> </tr> </thead> <tbody> <tr> <td>Custos de não qualidade (NCF e Pn com responsabilidade SC e Fabrico) / Volume de faturação PROD</td> <td>-20%</td> </tr> <tr> <td>Número não conformidades / secção</td> <td>-20%</td> </tr> </tbody> </table>	KPI	Objetivo	Custos de não qualidade (NCF e Pn com responsabilidade SC e Fabrico) / Volume de faturação PROD	-20%	Número não conformidades / secção	-20%	6. VALIDAÇÃO DE SOLUÇÕES 	9. LIÇÕES APRENDIDAS E AÇÕES FUTURAS  Sistema RFID
KPI	Objetivo							
Custos de não qualidade (NCF e Pn com responsabilidade SC e Fabrico) / Volume de faturação PROD	-20%							
Número não conformidades / secção	-20%							
Responsável do projeto: Pedro Santos	Equipa: Pedro Santos, Fernando Carvalho, Eládio Pires, Sofia Pinto e Catarina Mourato	Aprovado por: Fernando Carvalho						

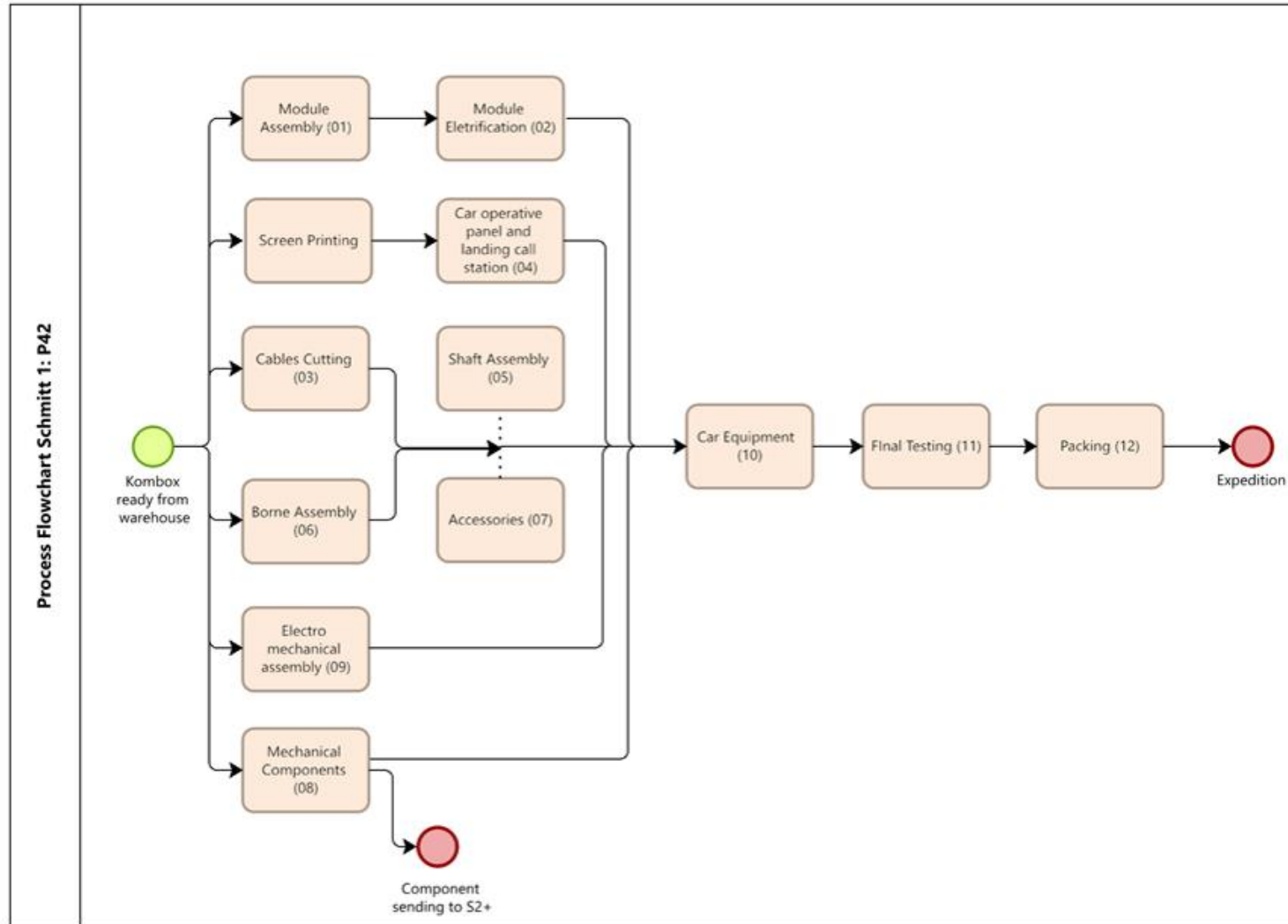
APPENDIX B: Schmitt 2 Floor Plan



APPENDIX C: In process flowchart *Schmitt 2*



APPENDIX D: In process flowchart *Schmitt 1*



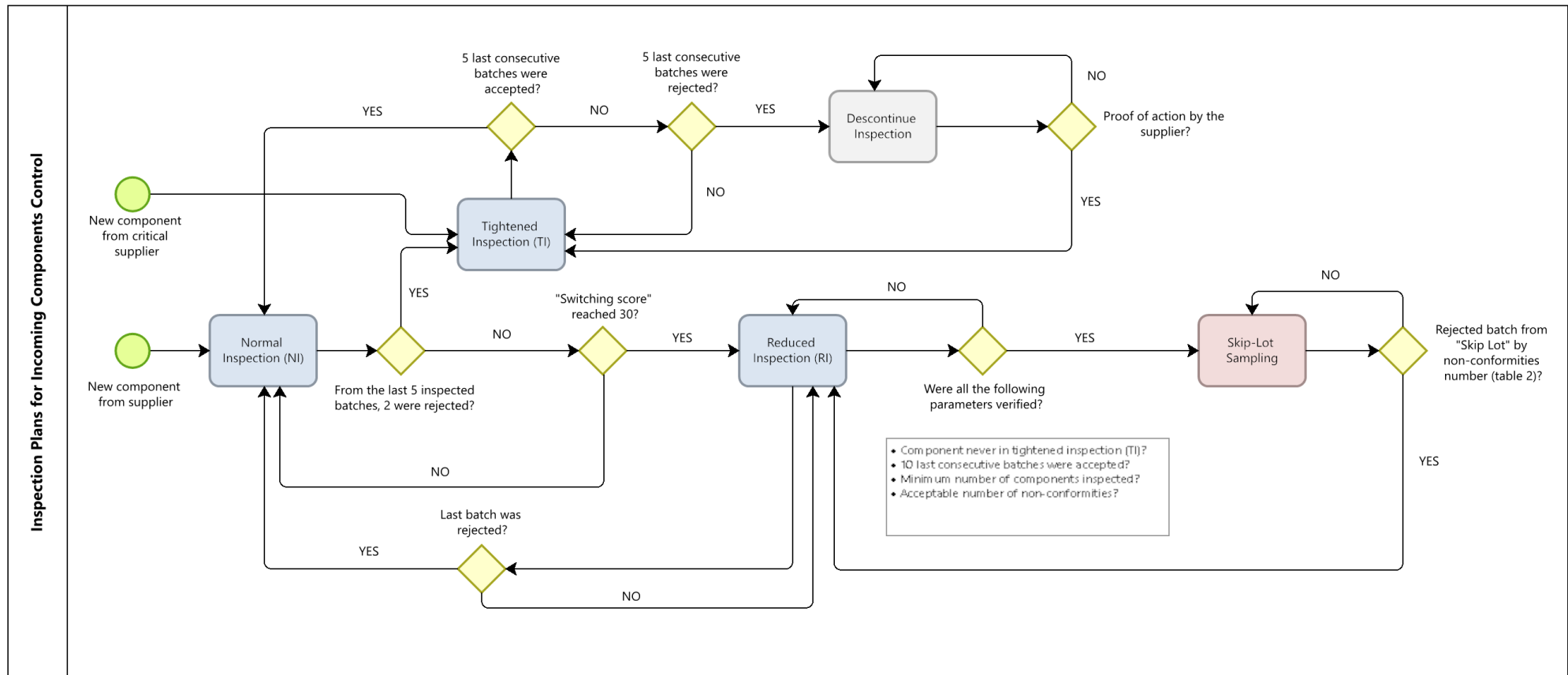
APPENDIX E: MUDA Hunting Template

Secção: Operador:		Análise do Modo de Operação			Data:
VA (acumulado)	MUDA (acumulado)	Descrição da Operação	VA / Operação	Comentários	Layout - Diagrama de Spaghetti
				# unids	
					7 MUDA
					1 - Espera (Pessoas)
					2 - Transporte (peças/material)
					3 - Sobreprocessamento
					4 - Inventário (peças/material)
					5 - Movimento (pessoas)
					6 - Defeitos
TOTAL VA	TOTAL MUDA				7 - Sobreprodução

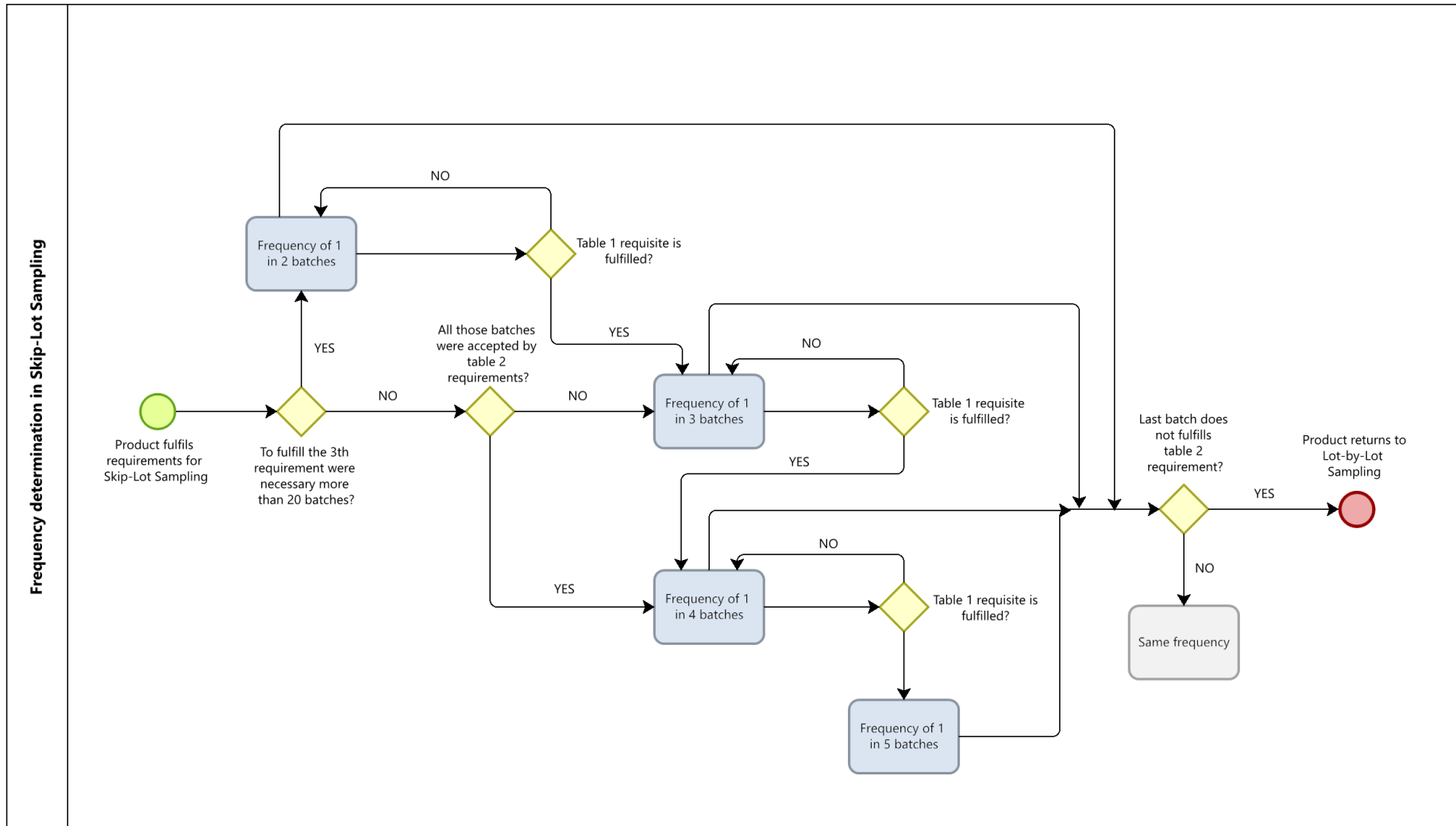
APPENDIX F: MUDA Hunting of dimensional control registration in Excel

Caça ao MUDA: Registo de Controlos Dimensionais		
VA	MUDA	Descrição Operação
	01:15	Preencher <i>Comboboxs</i>
	02:00	Abrir desenho
	01:30	Inserir cotas nominais
00:30		Inserir cotas medidas
00:30	04:45	
% MUDA	90,5%	

APPENDIX G: Flowchart of integration of ISO 2859-1 and ISO 2859-3



APPENDIX H: Flowchart of frequencies within Skip-Lot Sampling



APPENDIX I: VBA code for the created interface for the incoming products quality control

```
Private Sub CommandButton1_Click()

Dim contame As Integer
Dim contanao As Integer

Set tabela = Sheets("Registo Controlo").Range("A1").CurrentRegion
linhas = Sheets("Registo Controlo").Range("A1").CurrentRegion.Rows.Count

Dim i As Integer
For i = linhas To 2 Step -1
    If TextBoxNV.Text = tabela(i, 2).Text Then
        TextBoxPI.Text = tabela(i, 3).Text
        Exit For
    End If
Next

If TextBoxPI.Text = "SL" Then
    For i = linhas To 2 Step -1
        If TextBoxNV.Text = tabela(i, 2).Text Then
            TextBoxFreq.Text = tabela(i, 4).Text
            Exit For
        End If
    Next
    For i = linhas To 2 Step -1
        If TextBoxNV.Text = tabela(i, 2).Text And TextBoxPI.Text = "SL" Then
            If TextBoxFreq.Text = "1 em 3" Then
                If tabela(i, 5) = "Não" And tabela(i - 1, 5) = "Não" Then
                    TextBoxVerifica = "Sim"
                    Exit For
                Else
                    TextBoxVerifica = "Não"
                    TextBoxDim.Enabled = False
                    TextBoxAmostra.Enabled = False
                    TextBoxAc.Enabled = False
                    TextBoxNCFs.Enabled = False
                    cinza = RGB(46, 46, 46)
                    TextBoxDim.BackColor = cinza
                End If
            End If
        End If
    Next
End For
```

```
        TextBoxAmostra.BackColor = cinza
        TextBoxAc.BackColor = cinza
        TextBoxNCFs.BackColor = cinza
    End If
End If
If TextBoxFreq.Text = "1 em 4" Then
    If tabela(i, 5) = "Não" And tabela(i - 1, 5) = "Não" And tabela(i - 2, 5) = "Não" Then
        TextBoxVerifica = "Sim"
        Exit For
    Else
        TextBoxVerifica = "Não"
        TextBoxDim.Enabled = False
        TextBoxAmostra.Enabled = False
        TextBoxAc.Enabled = False
        TextBoxNCFs.Enabled = False
        cinza = RGB(46, 46, 46)
        TextBoxDim.BackColor = cinza
        TextBoxAmostra.BackColor = cinza
        TextBoxAc.BackColor = cinza
        TextBoxNCFs.BackColor = cinza
    End If
End If
If TextBoxFreq.Text = "1 em 5" Then
    If tabela(i, 5) = "Não" And tabela(i - 1, 5) = "Não" And tabela(i - 2, 5) = "Não" And tabela(i - 3, 5) = "Não" Then
        TextBoxVerifica = "Sim"
        Exit For
    Else
        TextBoxVerifica = "Não"
        TextBoxDim.Enabled = False
        TextBoxAmostra.Enabled = False
        TextBoxAc.Enabled = False
        TextBoxNCFs.Enabled = False
        cinza = RGB(46, 46, 46)
        TextBoxDim.BackColor = cinza
        TextBoxAmostra.BackColor = cinza
        TextBoxAc.BackColor = cinza
        TextBoxNCFs.BackColor = cinza
    End If
End If
End If
```

```

Next
End If

Dim answer0 As Integer
If tabela(i, 3).Text = "Descontinuada" Then
    answer0 = MsgBox("A inspeção deste produto foi descontinuada. O fornecedor tomou algum tipo de ação?", vbQuestion +
vbYesNo + vbDefaultButton2, "")
    If answer0 = vbNo Then
        MsgBox ("Não é possível registrar este produto")
        UserForm3.Hide
        TextBoxNV.Text = ""
        ComboBoxFornecedor.Text = ""
        TextBoxPI.Text = ""
    Else
        TextBoxPI.Text = "IA"
        TextBoxVerifica.Text = "Sim"
        TextBoxFreq.Text = "1 em 1"
    End If
End If

Else
    Dim answer As Integer
    If TextBoxPI.Text = "" Then
        answer = MsgBox("Novo código Navision: este fornecedor é crítico?", vbQuestion + vbYesNo + vbDefaultButton2,
        "")
        If answer = vbYes Then
            TextBoxPI.Text = "IA"
        Else
            TextBoxPI.Text = "IN"
        End If
    End If
End If

If TextBoxPI.Text = "IN" Or TextBoxPI.Text = "IA" Or TextBoxPI.Text = "IR" Then
    TextBoxVerifica.Text = "Sim"
    TextBoxFreq.Text = "1 em 1"
End If
End If
End Sub

Private Sub CommandButton2_Click()
    Dim n As Integer

```

```

n = TextBoxDim.Text

If TextBoxPI.Text = "IN" Or TextBoxPI.Text = "SL" Then
    Set tabelaIN = Sheets("Plano IN").Range("A1").CurrentRegion
    For i = 2 To 13
        If n >= tabelaIN(i, 1).Text And n <= tabelaIN(i, 2) Then
            TextBoxAmostra.Text = tabelaIN(i, 3).Text
            TextBoxAc.Text = tabelaIN(i, 4).Text
        Exit For
    End If
Next
End If

If TextBoxPI.Text = "IA" Then
    Set TabelaIA = Sheets("Plano IA").Range("A1").CurrentRegion
    For i = 2 To 13
        If n >= TabelaIA(i, 1).Text And n <= TabelaIA(i, 2) Then
            TextBoxAmostra.Text = TabelaIA(i, 3).Text
            TextBoxAc.Text = TabelaIA(i, 4).Text
        Exit For
    End If
Next
End If

If TextBoxPI.Text = "IR" Then
    Set TabelaIR = Sheets("Plano IR").Range("A1").CurrentRegion
    For i = 2 To 13
        If n >= TabelaIR(i, 1).Text And n <= TabelaIR(i, 2) Then
            TextBoxAmostra.Text = TabelaIR(i, 3).Text
            TextBoxAc.Text = TabelaIR(i, 4).Text
        Exit For
    End If
Next
End If

End Sub

Private Sub CommandButton3_Click()
    Dim aceitacao As Integer

```

```
If TextBoxPI.Text = "SL" And TextBoxVerifica.Text = "Não" Then
```

```
    aceitacao = 1
```

```
    TextBoxPos.Text = "SL"
```

```
Else
```

```
    If TextBoxNCFs.Text <= TextBoxAc.Text Then
```

```
        aceitacao = 1
```

```
        MsgBox ("O lote foi aceite.")
```

```
    Else
```

```
        aceitacao = 0
```

```
        MsgBox ("O lote não foi aceite.")
```

```
    End If
```

```
End If
```

```
'Set tabelacontroles = Sheets("Registo Controlo").Range("A1").CurrentRegion
```

```
'linhas = Sheets("Registo Controlo").Range("A1").CurrentRegion.Rows.Count
```

```
'Dim novalinha As ListRow
```

```
'Set novalinha = tabelacontroles.Rows.Add
```

```
'With novalinha
```

```
    '.Range(1) = ComboBoxFornecedor.Text
```

```
    '.Range(2) = TextBoxNV.Text
```

```
    '.Range(3) = TextBoxPI.Text
```

```
    '.Range(6) = TextBoxDim.Text
```

```
    '.Range(7) = TextBoxAmostra.Text
```

```
    '.Range(8) = aceitacao
```

```
'End With
```

```
Sheets("Registo Controlo").Select
```

```
i = 1
```

```
Do Until Cells(i, 1) = ""
```

```
    i = i + 1
```

```
Loop
```

```
Cells(i, 1) = ComboBoxFornecedor.Text
```

```
Cells(i, 2) = TextBoxNV.Text
```

```
Cells(i, 3) = TextBoxPI.Text
```

```
Cells(i, 4) = TextBoxFreq.Text
```

```
Cells(i, 5) = TextBoxVerifica.Text
```

```
Cells(i, 6) = TextBoxDim.Text
```

```

Cells(i, 7) = TextBoxAmostra.Text
Cells(i, 8) = TextBoxAc.Text
Cells(i, 9) = aceitacao
Cells(i, 11) = TextBoxNCFs.Text

'De apertada para descontinuar inspeção
Dim contador As Integer
Dim contar As Integer
If aceitacao = 0 And TextBoxPI.Text = "IA" Then
    linhas = Sheets("Registo Controlo").Range("A1").CurrentRegion.Rows.Count
    For i = linhas To 2 Step -1
        Sheets("Registo Controlo").Select
        If Cells(i, 2).Text = TextBoxNV.Text Then
            contar = contar + 1
            If Cells(i, 3).Text = "IA" Then
                If Cells(i, 9) = 0 Then
                    contador = contador + 1
                    If contador = 5 Then
                        MsgBox ("Últimos 5 lotes foram rejeitados: descontinuar inspeção")
                        TextBoxPos.Text = "Descontinuada"
                        Exit For
                    End If
                End If
            Else
                'MsgBox ("Dos últimos 4 algum foi aceite")
                TextBoxPos.Text = "IA"
                Exit For
            End If
        End If
    Next
End If

'De apertada para normal
Dim conta As Integer

```

```

Dim contad As Integer
If aceitacao = 1 And TextBoxPI.Text = "IA" Then
    linhas = Sheets("Registo Controlo").Range("A1").CurrentRegion.Rows.Count
    For i = linhas To 2 Step -1
        Sheets("Registo Controlo").Select
        If Cells(i, 2).Text = TextBoxNV.Text Then
            contad = contad + 1
            If Cells(i, 3).Text = "IA" Then
                If Cells(i, 9) = 1 Then
                    conta = conta + 1
                    If conta = 5 Then
                        MsgBox ("Últimos 5 lotes foram aceites: passar para inspeção normal")
                        TextBoxPos.Text = "IN"
                        Cells(linhas, 10) = 0
                        Exit For
                    End If
                Else
                    'MsgBox ("Dos últimos 4 algum foi rejeitado")
                    TextBoxPos.Text = "IA"
                    Exit For
                End If
            End If
        End If
        If contad = 5 Then
            TextBoxPos.Text = "IA"
            Exit For
        End If
    End If
Next
End If

```

```

'De normal para apertada
Dim contas As Integer
Dim soma As Integer
If aceitacao = 0 And TextBoxPI.Text = "IN" Then
    linhas = Sheets("Registo Controlo").Range("A1").CurrentRegion.Rows.Count
    For i = linhas To 2 Step -1
        Sheets("Registo Controlo").Select
        If Cells(i, 2).Text = TextBoxNV.Text Then
            soma = soma + Cells(i, 9).Text
            contas = contas + 1

```

```

If contat = 5 Then
    If soma > 3 Then
        MsgBox ("Apenas 0 ou 1 lotes rejeitados, continuar IN.")
        TextBoxPos.Text = "IN"
        Exit For
    Else
        MsgBox ("2 ou mais lotes rejeitados, passar para IA.")
        TextBoxPos.Text = "IA"
        Exit For
    End If
End If
End If
Next
End If

'De reduzida para normal
If aceitacao = 0 And TextBoxPI.Text = "IR" Then
    MsgBox ("Lote rejeitado em reduzida, passar para IN")
    TextBoxPos.Text = "IN"
    linhas = Sheets("Registo Controlo").Range("A1").CurrentRegion.Rows.Count
    Cells(linhas, 10) = 0
End If

'De normal para reduzida

Dim SS As Integer
If aceitacao = 1 And TextBoxPI.Text = "IN" Then
    linhas = Sheets("Registo Controlo").Range("A1").CurrentRegion.Rows.Count
    For i = linhas - 1 To 2 Step -1
        Sheets("Registo Controlo").Select
        If Cells(i, 2).Text = TextBoxNV.Text Then
            SS = Cells(i, 10)
            If TextBoxAc.Text < 2 Then 'SS não necessita de AQL mais apertado
                SS = SS + 2
                Cells(linhas, 10) = SS
            End If
            If SS >= 30 Then
                MsgBox ("SS atingiu 30, passar para plano IR")
                TextBoxPos.Text = "IR"
                Cells(linhas, 10) = 0
            End If
        End If
    Next i
End For

```

```

Else
    TextBoxPos.Text = "IN"
    Exit For
End If

Else 'SS necessita de AQL mais apertado

    Dim num As Integer
    Dim aql As Integer
    num = TextBoxDim.Text
    Set tabelaIN = Sheets("Plano IN").Range("A1").CurrentRegion
    For j = 2 To 13
        If num >= tabelaIN(j, 1).Text And num <= tabelaIN(j, 2) Then
            aql = tabelaIN(j, 5)
            Exit For
        End If
    Next
    If TextBoxNCFs.Text < aql Then
        SS = SS + 3
        Cells(linhas, 10) = SS
        If SS >= 30 Then
            MsgBox ("SS atingiu 30, passar para plano IR")
            TextBoxPos.Text = "IR"
            Cells(linhas, 10) = 0
            Exit For
        Else
            TextBoxPos.Text = "IN"
            Exit For
        End If
    Else
        MsgBox ("Lote não aceite no nível AQL mais restrito, reset SS para 0")
        Cells(linhas, 10) = 0
        TextBoxPos.Text = "IN"
        Exit For
    End If
End If

End If

Next

End If

If aceitacao = 0 And TextBoxPI.Text = "IN" Then
    Cells(linhas, 10) = 0

```

End If

'reduzida para skip-lot

Dim contalinhas As Integer

Dim sum As Integer

Dim contame As Integer

Dim contancfs As Integer

Dim contaamostra As Integer

Dim flag3 As Boolean

flag3 = False

Dim contaf As Integer

Dim freq1em4 As Boolean

If aceitacao = 1 And TextBoxPI = "IR" Then

contalinhas = Sheets("Registo Controlo").Range("A1").CurrentRegion.Rows.Count

For i = contalinhas To 2 Step -1

If Cells(i, 2).Text = TextBoxNV.Text Then

sum = sum + Cells(i, 9).Text

contame = contame + 1

contancfs = contancfs + Cells(i, 11)

contaamostra = contaamostra + Cells(i, 7).Text

If Cells(i, 3).Text = "IA" Then

MsgBox ("Já esteve em IA")

TextBoxPos.Text = "IR"

flag1 = True

Exit For

End If

If contame = 10 Then

If sum < 10 Then

MsgBox ("10 últimos lotes não foram todos aceites")

TextBoxPos.Text = "IR"

flag2 = True

Exit For

End If

Set tabela1 = Sheets("Tabela1_sl").Range("A1").CurrentRegion

For j = 2 To 22

If tabela1(j, 1) = contancfs Then

If tabela1(j, 2) > contaamostra Then

MsgBox ("Número minimo de amostragem não verificado")

```

        TextBoxPos.Text = "IR"

        flag3 = True

        Exit For

    End If

End If

Next

Exit For

End If

If contame <= 2 Then

    Set tabela2 = Sheets("Tabela2_sl").Range("A1").CurrentRegion

    For j = 2 To 11

        If Cells(i, 7) = tabela2(j, 1) Then

            If Cells(i, 11) > tabela2(j, 2) Then

                MsgBox ("Número aceitável de ncfs não verificado")

                flag = True

                TextBoxPos.Text = "IR"

                flag4 = True

                Exit For

            End If

        End If

    Next

    If flag = True Then

        Exit For

    End If

End If

End If

Next

If flag1 = False And flag2 = False And flag3 = False And flag4 = False Then

    MsgBox ("Produto cumpre requisitos para skip-lot sampling.")

    TextBoxPos.Text = "SL"

    TextBoxVerifica.Text = "Sim"

    contalinhas = Sheets("Registo Controlo").Range("A1").CurrentRegion.Rows.Count

    For i = contalinhas To 2 Step -1

        If contaf = 10 Then

            Exit For

        End If

        If Cells(i, 2).Text = TextBoxNV.Text Then

            contaf = contaf + 1

            Set tabela2 = Sheets("Tabela2_sl").Range("A1").CurrentRegion

            For j = 2 To 11

```

```

        If Cells(i, 7) = tabela2(j, 1) Then
            If Cells(i, 11) > tabela2(j, 2) Then
                TextBoxFreq.Text = "1 em 3"
                flagout = True
                Exit For
            End If
        End If
        TextBoxFreq.Text = "1 em 4"
    Next
    If flagout = True Then
        Exit For
    End If
End If
Next

End If
End If

'skip-lot para reduzida
If TextBoxPI.Text = "SL" Then
    linhas = Sheets("Registo Controlo").Range("A1").CurrentRegion.Rows.Count
    If Cells(linhas, 2).Text = TextBoxNV.Text Then
        Set tabela2 = Sheets("Tabela2_sl").Range("A1").CurrentRegion
        For i = 2 To 11
            If Cells(linhas, 7) = tabela2(i, 1) Then
                If Cells(linhas, 11) > tabela2(i, 2) Then
                    MsgBox ("Numero máximo ncfs ultrapassado, regresso a plano reduzido.")
                    TextBoxPos.Text = "IR"
                    TextBoxVerifica.Text = "Sim"
                    TextBoxFre.Text = "1 em 1"
                    Exit For
                End If
            End If
        Next
    End If
End If

'freq 1/3 para freq 1/4
Dim conte As Integer
Dim somame As Integer

```

```

Dim somas As Integer

If TextBoxPI.Text = "SL" And TextBoxFreq.Text = "1 em 3" Then

    linhas = Sheets("Registo Controlo").Range("A1").CurrentRegion.Rows.Count

    For i = linhas To 2 Step -1

        If Cells(i, 2).Text = TextBoxNV.Text And Cells(i, 4) = "1 em 3" Then

            conte = conte + 1

            somame = somame + Cells(i, 11) 'ncfs

            somas = somas + Cells(i, 7) 'amostra

            If conte = 10 Then

                Set tabela1 = Sheets("Tabela1_sl").Range("A1").CurrentRegion

                For j = 2 To 22

                    If tabela1(j, 1) = somame Then

                        If tabela1(j, 2) <= somas Then

                            MsgBox ("Redução de frequência de inspeção.")

                            TextBoxFreq.Text = "1 em 4"

                            TextBoxPos.Text = "SL"

                            Exit For

                        Else

                            TextBoxPos.Text = "SL"

                            Exit For

                        End If

                    End If

                Next

                Exit For

            End If

        End If

    Next

Else

    conte = 0

    TextBoxPos.Text = "SL"

    Exit For

End If

Next

'freq 1/4 para 1/5

Dim conte2 As Integer

Dim somame2 As Integer

Dim somas2 As Integer

If TextBoxPI.Text = "SL" And TextBoxFreq.Text = "1 em 4" Then

    linhas = Sheets("Registo Controlo").Range("A1").CurrentRegion.Rows.Count

    For i = linhas To 2 Step -1

```

```

If Cells(i, 2).Text = TextBoxNV.Text And Cells(i, 4) = "1 em 4" Then
    conte2 = conte2 + 1
    somame2 = somame2 + Cells(i, 11) 'ncfs
    somas2 = somas2 + Cells(i, 7) 'amostra
    If conte2 = 10 Then
        Set tabela1 = Sheets("Tabela1_sl").Range("A1").CurrentRegion
        For j = 2 To 22
            If tabela1(j, 1) = somame2 Then
                If tabela1(j, 2) <= somas2 Then
                    MsgBox ("Redução de frequência de inspeção.")
                    TextBoxFreq.Text = "1 em 5"
                    TextBoxPos.Text = "SL"
                    Exit For
                Else
                    TextBoxPos.Text = "SL"
                    Exit For
                End If
            End If
        Next
        Exit For
    End If
Else
    conte = 0
    TextBoxPos.Text = "SL"
    Exit For
End If
Next
End If

End Sub

```

```

Private Sub CommandButton4_Click()

```

```

    Sheets("Registo Controlo").Select
    linhas = Sheets("Registo Controlo").Range("A1").CurrentRegion.Rows.Count
    Cells(linhas, 3) = TextBoxPos.Text
    Cells(linhas, 4) = TextBoxFreq.Text

```

ComboBoxFornecedor = ""

TextBoxNV.Text = ""

TextBoxPos.Text = ""

TextBoxDim.Text = ""

TextBoxVerifica.Text = ""

TextBoxPI.Text = ""

TextBoxFreq.Text = ""

TextBoxAmostra.Text = ""

TextBoxAc.Text = ""

TextBoxNCFs.Text = ""

TextBoxDim.Enabled = True

TextBoxAmostra.Enabled = True

TextBoxAc.Enabled = True

TextBoxNCFs.Enabled = True

branco = RGB(255, 255, 255)

TextBoxDim.BackColor = branco

TextBoxAmostra.BackColor = branco

TextBoxAc.BackColor = branco

TextBoxNCFs.BackColor = branco

End Sub

Private Sub UserForm_Initialize()

branco = RGB(255, 255, 255)

azul = RGB(5, 79, 119)

UserForm3.BackColor = branco

Label3.BackColor = branco

Label16.BackColor = branco

Label17.BackColor = branco

Label32.BackColor = branco

Label30.BackColor = branco

Label31.BackColor = branco

Label33.BackColor = branco

Label36.BackColor = branco

Label35.BackColor = branco

Label34.BackColor = branco

Label3.ForeColor = azul

```
Label16.ForeColor = azul  
Label17.ForeColor = azul  
Label32.ForeColor = azul  
Label30.ForeColor = azul  
Label31.ForeColor = azul  
Label33.ForeColor = azul  
Label36.ForeColor = azul  
Label35.ForeColor = azul  
Label34.ForeColor = azul  
End Sub
```

APPENDIX J: VBA code to import the data from the SQL platform

```

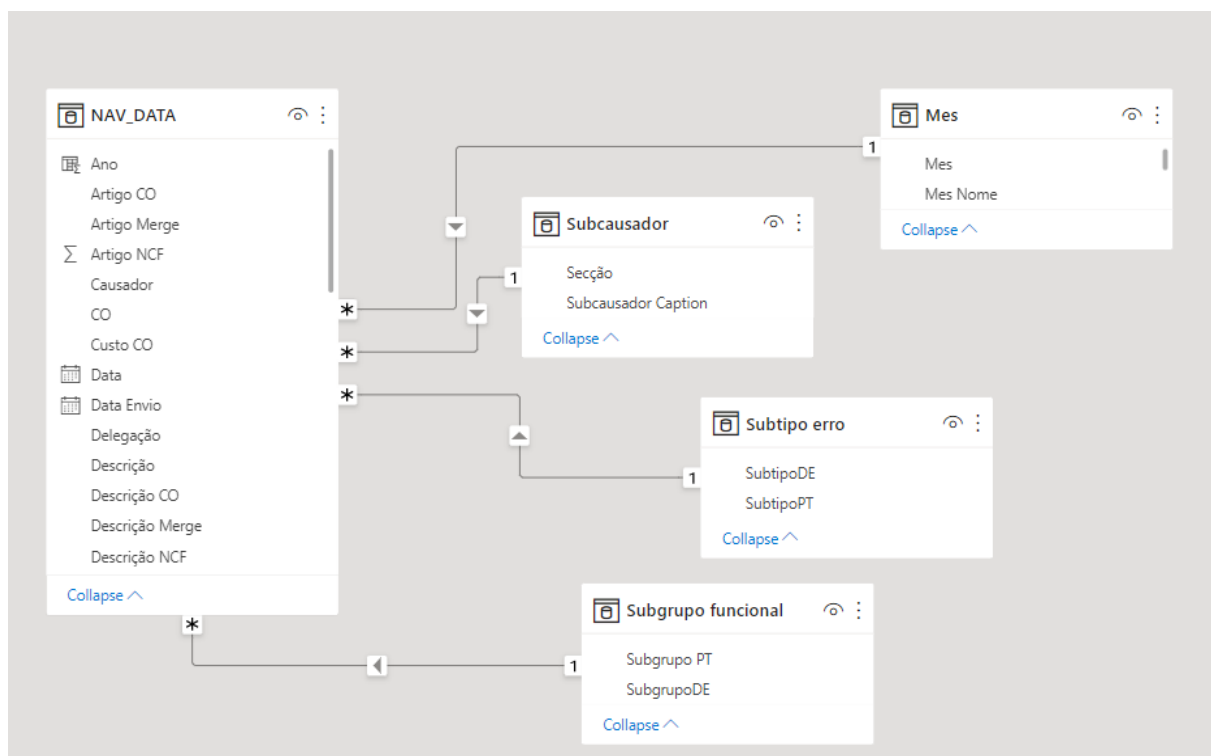
strquery = "SELECT t1.""Document No_"" , t1.""Order Date"" , t1.""Aufzugsnr_"" , t1.""Aufzugstyp"" ,
t1.""Baugruppe"" , t1.""Fehlerart"" , t1.""Shipment Date"" , t1.""Mehrleistung (Std)"" , t1.""Fremdrechnungsbe
trag (EUR)"" , t1.""ZN"" , t1.""Fehlerbehebung komplett"" ,
strquery = strquery & " t1.""Verursacher"" , t2.""Input"" AS ""KVRBAM"" , t3.""Input"" AS ""KUVUB
AM"" , t5.""No_"" , t5.""Description"" , t5.""Quantity"" , t5.""Unit Cost"" , (t5.""Quantity""*t5.""Unit Co
st""), t4.""_text"" , "
strquery = strquery & " tabelaCO.""No_"" , tabelaCO.""Nr_"" , tabelaCO.""Beschreibung"" , tabelaCO
.""Calculation Cost Component"" , tabelaCO.""erw_ Menge"" , t6.""Input"" , t7.""Input""
strquery = strquery & " FROM dbo.""BAM List Line"" t1 LEFT JOIN (SELECT t1.""Document No_"" , t1
.""No_"" , t2.""Nr_"" , t2.""Beschreibung"" , t2.""Calculation Cost Component"" , t2.""erw_ Menge"" FRO
M dbo.""Schmitt Elevadores LDA Porto$Konstruktionskopf"" t1"
strquery = strquery & " left join dbo.""Schmitt Elevadores LDA Porto$Konstruktionszeile"" t2 ON
t1.""No_""=t2.""Document No_"" AND t2.""Ebene"" = 3"
strquery = strquery & " WHERE t1.""Document No_"" LIKE 'NCF22%' AND t2.""Nr_"" not LIKE 'D%') AS
tabelaCO ON t1.""Document No_""= tabelaCO.""Document No_"" LEFT JOIN dbo.""Schmitt Elevadores LDA
Porto$Sales Line"" t5 ON t1.""Document No_""=t5.""Document No_"" AND t5.""No_""<>'BAM'"
strquery = strquery & " left JOIN dbo.""Checklistenzeile"" t2 ON t1.""Checklist No_""=t2.""Bele
gnr_"" AND t2.""Variable für dynam_ Stückliste""='KVRBAM'"
strquery = strquery & " left JOIN dbo.""Checklistenzeile"" t3 ON t1.""Checklist No_""=t3.""Bele
gnr_"" AND t3.""Variable für dynam_ Stückliste""='KUVUBAM'"
strquery = strquery & " left JOIN dbo.""Checklistenzeile"" t6 ON t1.""Checklist No_""=t6.""Bele
gnr_"" AND t6.""Variable für dynam_ Stückliste""='UKBAUBAM'"
strquery = strquery & " left JOIN dbo.""Checklistenzeile"" t7 ON t1.""Checklist No_""=t7.""Bele
gnr_"" AND t7.""Variable für dynam_ Stückliste""='KUFABAM'"
strquery = strquery & " LEFT JOIN (SELECT ""No_"" , string_agg(""Comment"" , ' ') AS ""_text"" FR
OM dbo.""Schmitt Elevadores LDA Porto$Sales Comment Line"" GROUP by ""No_"" ) t4 ON t1.""Document No
_""=t4.""No_""
strquery = strquery & " WHERE (t1.""Document No_"" LIKE 'NCF22%' OR t1.""Document No_"" LIKE 'N
CF21%') AND ""Verursacher"" IN ('Supply Chain', 'Produção') ORDER BY t1.""Order Date"""

'Performs the actual query
rst.Open strquery, cnn
Sheets("NAV_DATA").Range("A2").CopyFromRecordset rst

cnn.Close

```

APPENDIX K: Power BI Relational Model



APPENDIX L: IT - Updating and interpretation of Power BI data

**Instrução de Trabalho**

IT07.320/v1.0 Atualização e interpretação de dados das *Dashboards* criadas em *Power BI* para controlo de qualidade

1. Objetivo

A presente instrução de trabalho pretende normalizar o processo de atualização de dados e de determinação do plano diário de controlo de qualidade relativo à produção.

2. Âmbito

Válido para todas as atualizações de *NCFs* semanais necessárias na Schmitt-Elevadores

3. Documentos Associados

Nada a assinalar.

4. Definições

Nada a assinalar.

5. Responsabilidades

A responsabilidade pela garantia do cumprimento da presente instrução é do departamento de Qualidade, Ambiente e Segurança (QMB/AUB).

**6. Modo operativo**

Sequência de Operação	Imagem	Descrição da operação	Comentários
1		Abrir a pasta de rede "Group Share Schmitt PT" > "Projetos" > "Viver a Qualidade" > "Sistema Controlo Qualidade".	
2		Abrir o ficheiro Excel "NCF_atualizar".	
3		Na folha de Excel "NAV_DATA", carregar no botão "ATUALIZAR".	



SCHMITT+SOHN
ELEVADORES

Instrução de Trabalho

IT07.320/v1.0 Atualização e interpretação de dados das *Dashboards* criadas em *Power BI* para controle de qualidade

4	Exceis Gráficos Histórico_PowerBI A3_Sistema para controlo de qualidade.... A3 Sistema para controlo de qualidade.p... AnaliseNFC_final.pbix NCF_atualizar.xlsm	Abrir o ficheiro Power BI "AnaliseNCF_final".																																																																																																													
5		Abrir a folha "PROD".																																																																																																													
6	Data 19-06-2021 30-05-2022 	Filtrar por data, de forma a seleccionar apenas os últimos 6 meses.																																																																																																													
7	Tipo de desvio: NCF Pre Selecção F10 F12 F14 F16 F18 F20	Garantir que nenhum tipo de desvio ou secção estão seleccionados.																																																																																																													
8	<table border="1"> <thead> <tr> <th>Subgrupo Funcional</th><th>Quantidade</th><th>% Desvio</th><th>% Com Desvio</th><th>Estado</th><th>Nº Controlos</th></tr> </thead> <tbody> <tr> <td>Folha</td><td>62</td><td>26,03%</td><td>26,03%</td><td>🔴</td><td>12</td></tr> <tr> <td>Fixação</td><td>24</td><td>7,62%</td><td>33,65%</td><td>🔴</td><td>4</td></tr> <tr> <td>Fanels</td><td>21</td><td>6,67%</td><td>40,57%</td><td>🔴</td><td>3</td></tr> <tr> <td>Punção de serviço integrado</td><td>10</td><td>5,00%</td><td>50,00%</td><td>🔴</td><td>2</td></tr> <tr> <td>Punção std</td><td>16</td><td>5,00%</td><td>30,40%</td><td>🟡</td><td>2</td></tr> <tr> <td>Bolacha</td><td>12</td><td>3,67%</td><td>54,29%</td><td>🟡</td><td>2</td></tr> <tr> <td>Fixação/Aparafusagem</td><td>11</td><td>3,60%</td><td>57,27%</td><td>🟡</td><td>2</td></tr> <tr> <td>Polvo - palmar</td><td>9</td><td>2,00%</td><td>60,00%</td><td>🟡</td><td>1</td></tr> <tr> <td>Paia superior</td><td>8</td><td>2,54%</td><td>63,17%</td><td>🟡</td><td>1</td></tr> <tr> <td>Paia inferior -</td><td>7</td><td>2,22%</td><td>67,62%</td><td>🟡</td><td>1</td></tr> <tr> <td>Cabeira</td><td>7</td><td>2,22%</td><td>67,62%</td><td>🟡</td><td>1</td></tr> <tr> <td>Transição</td><td>7</td><td>2,22%</td><td>67,62%</td><td>🟡</td><td>1</td></tr> <tr> <td>molta/peso</td><td>5</td><td>1,00%</td><td>70,79%</td><td>🟡</td><td>1</td></tr> <tr> <td>Cablagem</td><td>5</td><td>1,00%</td><td>70,79%</td><td>🟡</td><td>1</td></tr> <tr> <td>Expostos</td><td>5</td><td>1,00%</td><td>70,79%</td><td>🟡</td><td>1</td></tr> <tr> <td>Desmontagem</td><td>4</td><td>1,00%</td><td>75,00%</td><td>🟡</td><td>1</td></tr> <tr> <td>Total</td><td>315</td><td>100,00%</td><td></td><td></td><td>48</td></tr> </tbody> </table>	Subgrupo Funcional	Quantidade	% Desvio	% Com Desvio	Estado	Nº Controlos	Folha	62	26,03%	26,03%	🔴	12	Fixação	24	7,62%	33,65%	🔴	4	Fanels	21	6,67%	40,57%	🔴	3	Punção de serviço integrado	10	5,00%	50,00%	🔴	2	Punção std	16	5,00%	30,40%	🟡	2	Bolacha	12	3,67%	54,29%	🟡	2	Fixação/Aparafusagem	11	3,60%	57,27%	🟡	2	Polvo - palmar	9	2,00%	60,00%	🟡	1	Paia superior	8	2,54%	63,17%	🟡	1	Paia inferior -	7	2,22%	67,62%	🟡	1	Cabeira	7	2,22%	67,62%	🟡	1	Transição	7	2,22%	67,62%	🟡	1	molta/peso	5	1,00%	70,79%	🟡	1	Cablagem	5	1,00%	70,79%	🟡	1	Expostos	5	1,00%	70,79%	🟡	1	Desmontagem	4	1,00%	75,00%	🟡	1	Total	315	100,00%			48	Plano diário de controlo de qualidade definido na coluna "Nº Controlos".	
Subgrupo Funcional	Quantidade	% Desvio	% Com Desvio	Estado	Nº Controlos																																																																																																										
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Total	315	100,00%			48																																																																																																										
9	<table border="1"> <thead> <tr> <th>Subgrupo Funcional</th><th>Quantidade</th><th>% Desvio</th><th>% Com Desvio</th><th>Estado</th><th>Nº Controlos</th></tr> </thead> <tbody> <tr> <td>Folha</td><td>178</td><td>24,22%</td><td>24,22%</td><td>🔴</td><td>10</td></tr> <tr> <td>Folha</td><td>40</td><td>6,67%</td><td>25,00%</td><td>🔴</td><td>1</td></tr> <tr> <td>Fixação</td><td>88</td><td>1,57%</td><td>27,41%</td><td>🔴</td><td>1</td></tr> <tr> <td>Bolacha</td><td>46</td><td>5,20%</td><td>43,48%</td><td>🔴</td><td>1</td></tr> <tr> <td>Fanels</td><td>35</td><td>4,57%</td><td>40,57%</td><td>🔴</td><td>1</td></tr> <tr> <td>Polvo - palmar</td><td>22</td><td>2,00%</td><td>54,55%</td><td>🔴</td><td>1</td></tr> <tr> <td>Punção de serviço</td><td>21</td><td>2,00%</td><td>57,14%</td><td>🔴</td><td>1</td></tr> <tr> <td>Punção integrado</td><td>14</td><td>1,00%</td><td>65,11%</td><td>🔴</td><td>1</td></tr> <tr> <td>Fixação/Aparafusagem</td><td>14</td><td>1,00%</td><td>62,10%</td><td>🔴</td><td>1</td></tr> <tr> <td>Paia inferior -</td><td>14</td><td>1,00%</td><td>62,10%</td><td>🔴</td><td>1</td></tr> <tr> <td>Paia superior</td><td>14</td><td>1,00%</td><td>62,10%</td><td>🔴</td><td>1</td></tr> <tr> <td>Transição</td><td>12</td><td>1,79%</td><td>66,67%</td><td>🔴</td><td>1</td></tr> <tr> <td>molta</td><td>12</td><td>1,00%</td><td>65,52%</td><td>🔴</td><td>1</td></tr> <tr> <td>Cablagem</td><td>10</td><td>1,00%</td><td>60,00%</td><td>🔴</td><td>1</td></tr> <tr> <td>Expostos</td><td>12</td><td>1,00%</td><td>65,52%</td><td>🔴</td><td>1</td></tr> <tr> <td>Desmontagem</td><td>10</td><td>1,00%</td><td>60,00%</td><td>🔴</td><td>1</td></tr> <tr> <td>Total</td><td>733</td><td>100,00%</td><td></td><td></td><td>49</td></tr> </tbody> </table>	Subgrupo Funcional	Quantidade	% Desvio	% Com Desvio	Estado	Nº Controlos	Folha	178	24,22%	24,22%	🔴	10	Folha	40	6,67%	25,00%	🔴	1	Fixação	88	1,57%	27,41%	🔴	1	Bolacha	46	5,20%	43,48%	🔴	1	Fanels	35	4,57%	40,57%	🔴	1	Polvo - palmar	22	2,00%	54,55%	🔴	1	Punção de serviço	21	2,00%	57,14%	🔴	1	Punção integrado	14	1,00%	65,11%	🔴	1	Fixação/Aparafusagem	14	1,00%	62,10%	🔴	1	Paia inferior -	14	1,00%	62,10%	🔴	1	Paia superior	14	1,00%	62,10%	🔴	1	Transição	12	1,79%	66,67%	🔴	1	molta	12	1,00%	65,52%	🔴	1	Cablagem	10	1,00%	60,00%	🔴	1	Expostos	12	1,00%	65,52%	🔴	1	Desmontagem	10	1,00%	60,00%	🔴	1	Total	733	100,00%			49	De forma a saber em que secção realizar o controlo, carregar diretamente em cima do nome do sub-grupo funcional.	
Subgrupo Funcional	Quantidade	% Desvio	% Com Desvio	Estado	Nº Controlos																																																																																																										
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Instrução de Trabalho

IT07.320/v1.0 Atualização e interpretação de dados das *Dashboards* criadas em *Power BI* para controlo de qualidade

ower BI para o controlo de qualidade.

10

Gráfico de barras empilhadas e de linhas mostrando o número de desvios por secção e a percentagem de controlo. O gráfico tem dois eixos: o eixo Y esquerdo para 'Desvios' (0 a 200) e o eixo Y direito para '% Desvios' (0% a 60%). O eixo X mostra as secções F10, F41, F42, F43, F40, F30 e F20. As barras azuis representam o número de desvios, e as barras cinzentas representam a percentagem de controlo. Linhas vermelhas indicam os valores de controlo para cada secção: F10 (55,00%), F41 (55,00%), F42 (55,00%), F43 (55,00%), F40 (55,00%), F30 (55,00%) e F20 (55,00%).

Ao carregar no subgrupo funcional, o gráfico da esquerda vai apresentar as percentagens de controlo que devem ser feitas nas várias secções.

APPENDIX M: P42 Causes Analysis through the different cells

Em Processo: P42

Montagem de Quadros (01):	Variador módulo de potência está de acordo LP	Contactores e filtros de acordo LP	Amperagem dos disjuntores	Filtro EMC em concordância com o variador	Obras Stand Alone ou espaço reduzido: Kits Extra	Fontes de alimentação módulo de cabina de acordo LP	Obras com dois acessos: Kit Extra
Botoneiras (04):	Soldadura pernos botoneira de cabine	Cápsulas de acordo com preparação	Funciona- mento fitas LED e luzes dos botões	Gravação baixo-relevo de acordo desenho	Idioma da obra de acordo com preparação		
Instalação de caixa (05):	Terminais de acordo diagrama	Obras PLAT4, realização teste TestBox					
Assemblagem Bornes (06):	Bornes conforme diagrama	Réguas de acordo LP	Réguas identificadas com etiquetas				
Acessórios (07):	Kit sensor de excesso de carga	Filamento do barramento borne de acordo com LP					
Eletromecânica (09):	Fitas magnéticas de acordo com LP	Kits fixação fitas magnéticas	Suportes cabo de manobra de acordo LP	Armaduras de acordo LP	Ligação da resistência		
Equipar carro (10):	Etiquetas alta tensão	Identificação dos periféricos	Comprimen- to fitas magnéticas	Sistema Limax de acordo LP	Encoder de acordo LP	Obra X-Track: componentes a mais	
Ensaio Final (11):	Etiqueta amarela porta do comando	Obras PLAT1 ou PLAT5: etiqueta nomeação botões					
Embalagem (12):	Cabos elétricos: identificação e terminais	Aperto/ isolamento dos fios	Terminais instalação caixa	Filtros fio terra	Etiquetas prumo de serviço		

APPENDIX N: Example of an IT created after root causes analysis

**Instrução de Trabalho**

IT07.301/v1.0 Controlo de Qualidade do Posto de Trabalho Secção P42:
Botoneiras de Cabina/Patamar P42.04

1. Objetivo

A presente instrução pretende normalizar o controlo de qualidade a ser efetuado na secção P42 – Montagem Elétrica / Posto de Botoneiras de Cabina/Patamar - P42.04.

2. Âmbito

Válido para todos os controlos de qualidade realizados no posto P42.04 – Botoneiras de Cabina/Patamar, da Schmitt-Elevadores.

3. Documentos Associados

Nada a assinalar.

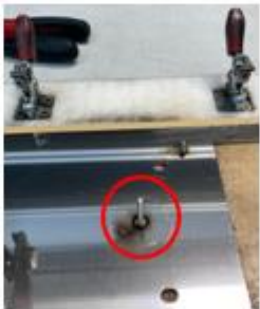
4. Definições

Nada a assinalar.

5. Responsabilidades

A responsabilidade pela garantia do cumprimento da presente instrução é do controlador de qualidade S1+.

6. Modo operativo

Sequência de Operação	Imagem	Descrição da operação	Comentários
1		Banca 1 (Botoneira de Cabina): Verificar se os parafusos estão corretamente soldados.	
2		Banca 2 (Montagem de componentes): Verificar concordância do tipo de cápsulas com preparação (cápsulas lisas, táteis, c/braille ou c/orla) e verificar concordância com desenho da gravação (se existir).	
3		Banca 3: Verificação do funcionamento das fitas led e das luzes dos botões (controlo visual).	

Instrução de Trabalho

IT07.301/v1.0 Controlo de Qualidade do Posto de Trabalho Secção P42:
Botoneiras de Cabina/Patamar P42.04

4		Banca 4: Verificar se gravação de baixo-relevo está de acordo com desenho. Verificar idioma da obra. Verificar se o tipo de cápsulas é concordante com o do ponto 2.	
5		Banca 4: Verificar se os pernos estão bem soldados.	

APPENDIX O: Example of an iAuditor Final Control Report

S+

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Relatório de Controlo de Qualidade

(Quality Control Report)

14 Jun 2022 / 383481-Paulo Rebelo

Complete

Score	100%	Flagged items	0	Actions	0
N.º documento/document n.º:	Relcq1406202208				
Realizado em/Inspection date:	14 Jun 2022 11:15 WEST				
Controlado Por/Controlled by:	383481-Paulo Rebelo				
Estabelecimento/Site:	S+2 - Fabrico Mecânico				
Localização/Location:	Porto				

Caracterização e localização do Controlo

(Control Characterization and location)

N.º de Obra/Lift N.º:

383481



Photo 1

Secção/Section	P43
Tipo de Controlo/Control Type:	Controlo no Processo
Forma de Controlo/Control format:	Controlo Visual, Dimensional e Funcional
N.º de Amostras/Total Samples:	1

Identificação de Grupo Componente Principal, Grupo e Subgrupo Funcional
(Group Identification of Main Component, Group and Functional Subgroup)

100%

Grupo componente principal, grupo e subgrupo funcional
(Main component group, functional group and subgroup)

100%

A que grupo de componente principal pertence a peça a inspecionar?
(To which major component group does the part to be inspected belong?)

Portas (B_Tueren)

A que grupo funcional pertence a peça a inspecionar?

Porta de Cabina (B_Kabinentuer)

A que subgrupo funcional pertence a peça a inspecionar?

Travessão: faca KTV (Kämpfer: Schwert KTV)

Inspeção/verificação da peça/componente
Part/component inspection/verification

100%

Os pernos do conjunto de rodas estão aplicados com loctite?
(Are the wheel set studs applied with loctite?)

Yes

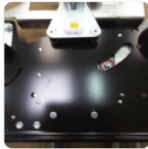


Photo 2

As rodas (conjunto de rodas) estão livres/não bloqueadas?
(Are the wheels (wheelset) free/not blocked?)

Yes

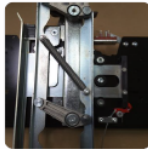


Photo 3

A rampa de reconhecimento movimenta-se autonomamente?
(Does the recognition ramp move autonomously?)

Yes



Photo 4



Photo 5

O cabo de desencravamento manual (após puxar) dá-se a abertura da porta?
(Does the manual release cable (after pulling) open the door?)

Yes

Private & Confidential

3/9



Photo 6

A articulação/movimento da rampas (curta e longa) movimentam-se sem dificuldade?
(Does the articulation/movement of the ramps (short and long) move without difficulty?)

Yes



Photo 7



Photo 8

Estado final do componente controlado (Final state of the controller component)

Estado Final/Final State:

Aprovado/(OK)



Photo 9



Photo 10

Observações

Declara-se para os devidos efeitos, que a peça/componente inspecionada pelo controlador de qualidade, encontra-se em devidas condições de funcionamento. Por esse facto, coloca-se como comprovativo de Aprovado, o selo de conformidade do material. Informa-se que foram efetuados registos fotográficos que acompanham o presente relatório de controlo de qualidade.

Qualquer anomalia, defeito de funcionamento, a peça deverá ser devolvida ao cuidado do Departamento QMB/AUB, fábrica S+ Porto. Qualquer alteração posterior efetuado à peça, dano provocado por terceiros ou outros registos/evidências de má utilização da mesma corresponderá a perda de garantia imediata sem qualquer tipo ressarcimento.

Comments

It is declared for all due purposes that the part/component inspected by the quality controller is in proper working condition. For this reason, the seal of conformity of the material is placed as proof of Approved. It is hereby informed that photographic records were made that accompany this quality control report. Any anomaly or malfunction, the part must be returned to the care of the QMB/AUB Department, S+ Porto factory. Any subsequent alteration made to the part, damage caused by third parties or other records/evidence of misuse of the same will correspond to the loss of the immediate warranty without any kind of compensation.

Assinaturas

(Signatures)

O Controlador de Qualidade:

Quality Control Operator:

Nome/Name:



14 Jun 2022 11:20 WEST

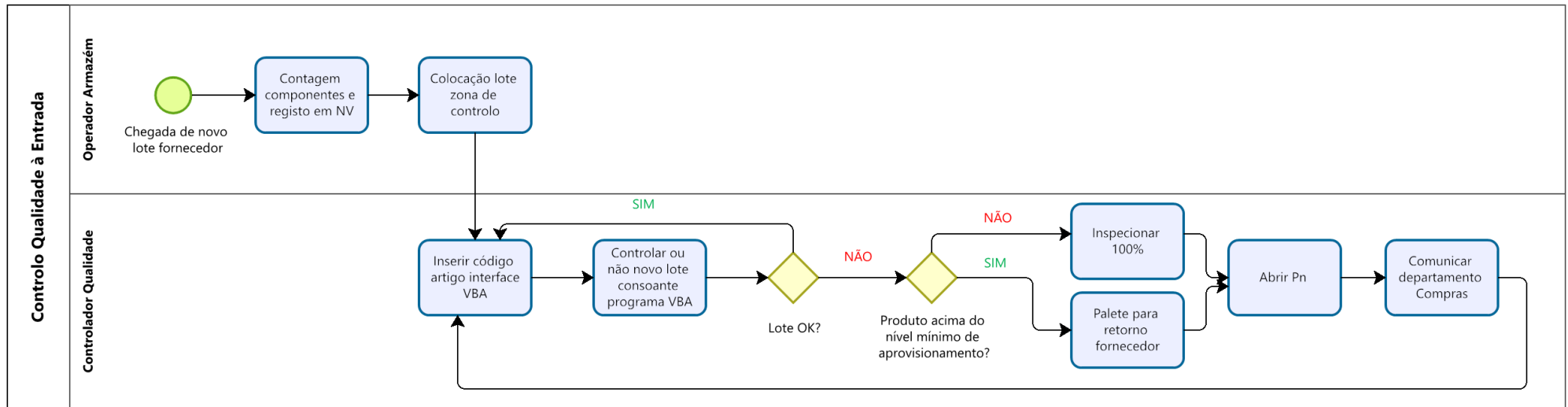
APPENDIX P: 8D Report



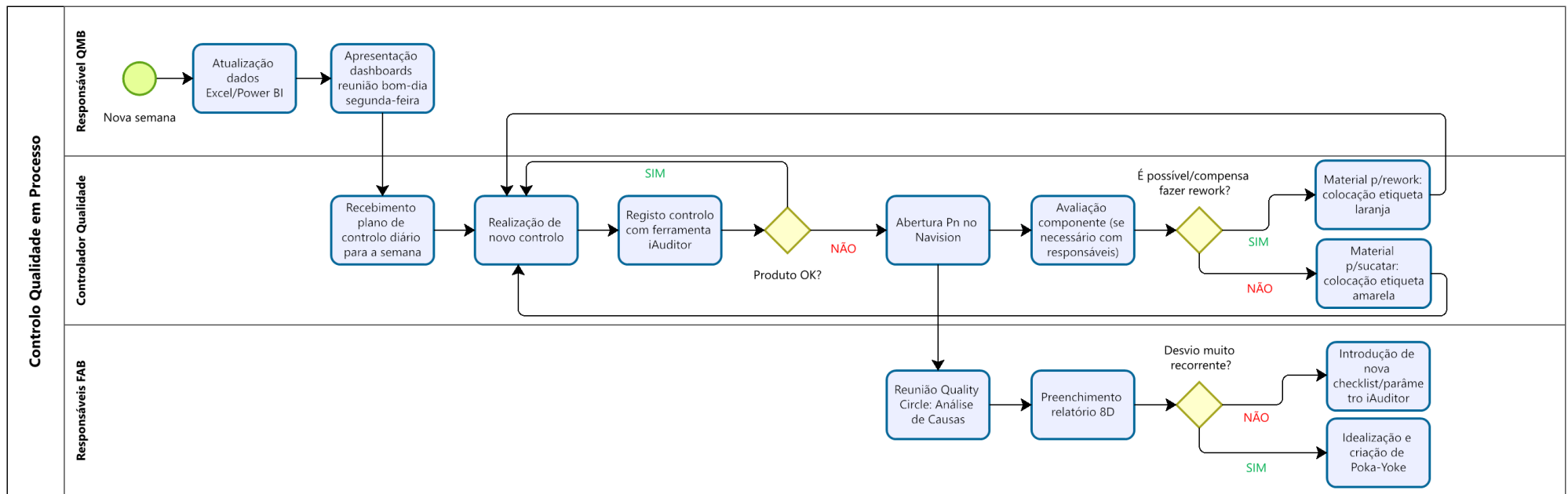
Relatório 8D

Título do Problema / Não Conformidade		Nº NCF:	Data:
Nº de Artigo:	Descrição:		
1 Formação da equipa	2 Descrição do problema		
3 Medida imediata:		Data de início:	
4 Causa raiz do Problema / Não Conformidade (Método, Material, Máquina, Pessoa, Ambiente):			
5 Comprovação da eficácia das ações corretivas:			
6 Implementar as ações corretivas		Data de início:	
7 Medidas preventivas contra reincidências:		Responsável:	
7a Transferibilidade para outras situações:			
8 Apresentação dos resultados / Fim:		Data fim / Autor:	

APPENDIX Q: Process Mapping for the Quality Control of the incoming products



APPENDIX R: Process Mapping for the Quality Control in-process



APPENDIX S: Process Mapping for the Quality Control before expedition

