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FEUP

Implementation of Lean Manufacturing in a SME

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Abstract

This project is part of the fourth phase - Optimization & Lean - of the installation of a manufacturing cell at a machining company, Castle Precision. The main subjects addressed in this project were the development and implementation of Standard Operation Procedures and Visual Management Boards.

The Standard Operation Procedures have the purpose of standardizing a certain task or process. Promoting safeness among the operators, reducing the variation of the process and non-conformities are some of the advantages when Standard Operations Procedures might have when implemented. In order to proceed to develop this documents for the cell, it was necessary to research on the shopfloor. By knowing the process, and also communicating with the operators, allowed to come up with a sequence of instructions of the process. These instructions were carefully written with the purpose of being simple and straightforward directions. These will guide the operators to complete their assignments in a consistent way, leading them to operate with less deviation from the standard and consequently with less appearance of non-conformities.

Along with Standard Operations Procedures, the Visual Management Boards were a main focus for this project. The purpose of having a Visual Management Board on the cell constantly being updated with the most recent information is clearly an advantage, not only for the operators to know at what stage their performance is, but also for the responsible to run the cell and at last for the management. The work developed on the board was to design and conceive key performance indicators to transmit useful information to whom consults the board. In order to complete this goal, a set of indicators were specifically designed. The result of the indicators was not only to share them on the board, but also originated tools to storage data in the background. The data storage is an advantage in terms of working as a traceability tool. The indicators integrated on the Visual Management Board were developed with the Microsoft Excel software and were: OEE, Attendance Tracker, Holiday Plans, Right First Time, On Time in Full, Launch on Time, Scrap & Rework and the Takt Time, [Setup], [Run] and [Overall].

Dedico esta dissertação ao meu sobrinho Daniel,

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List of abbreviations

TPS	Toyota Production System
JIT	Just in Time
WCM	World Class Mmanufacturing
LM	Lean Manufacturing
Muda	Waste in japanese
QFD	Qualtity Function Deployment
HOQ	House of Quality
WIP	Work In Progress
VA and NVA	Value Added and Non Value Added
OEE Metric	Overall equipment effectiveness
RFT Metric	Right First Time
NSCO	Normal Shift Clock Out
OTCO	Overtime Clock Out
EoNS	End of Normal Shift
EoOTS	End of Overtime Shift
OTIF Metric	On Time in Full
LoT Metric	Launch on Time
NCR	Non-Conformance Report
KPI	Key Performance Indicator

1.Introduction

1.1. Company's presentation

Castle Precision is a company established in 1951 by Jack Tiefunbrun as Textile Engineering Company, providing jigs, tools, fixtures and press tools. Later on, the company diversified itself from the textile industry, working with other more general engineering subcontractors that not textile and also manufacturing tools and other special machinery components. With the appearance of new technologies such as Computer Numerical Control (CNC) – the automation of machine tools which can be operated by programmed commands encoded [1-4].

The company was an early adopter of the CNC technology, acquiring, in 1971, their first CNC Mori-Seiki. During this period Castle bought the rights from the King Aircraft, in order to manufacture aircraft component. Naturally, the rise of the electronic and oil industry didn't take that much to represent a significant portion of Castle's turnover in the 1990s. At this stage, Castle Precision started to manufacture exotic alloys in a mainstream basis for the aerospace industry [1-4].

Nowadays, Castle Precision is a company with really strong knowledge in terms of machining, modelling and simulation, with processes capable of delivering quality products. Having over 60 CNC machines and using 5-axis machining technology, the company has its own tool making and design facility, also a unique self-costumed IT system which allows to trace and control at every level of the company, plus being, among others, AS 9100 certified (certification of management systems in aerospace, defence and space). The strong combination of such important variables to deliver quality products led the company to, in 2010, win the Scottish Engineering's Presidents Award for Achievement: The Manufacturers SME of Year and overall Manufacturer of the Year Awards.[1-4]

1.2. Description of the project and motivations

Recently Castle Precision won a contract to supply an aerospace company with five aero engine cones. These products are components from aero motors and because of that they have extremely high standard requirements. Since Castle Precision is a machining company, the requirements are quite accurate and precise about dimensional and roughness for example.

To celebrate the contract, Castle compromised to install a brand new aerospace production cell. The goal is to create the most efficient, effective and profitable machining solution for the client. Also, the company conceived a vision for the cone production cell, including:

- To set the standard for Castle lean cellular manufacture solutions.
- To develop a real competitive production cell in the cones market, winning a global share in the cone market industry.
- To create a cell ready to scale up its production if necessary.
- To create a self-managing and directed cell production team.

In order to do this, the project was divided into four parts:

- Phase 1 – Technical Concept & Design.
- Phase 2 – Cell Operation & Installation Planning.
- Phase 3 – Installation & Process prove out.
- Phase 4 – Optimisation & Lean.

The internship took place at the beginning of the fourth phase. This way, the main focus of the project allocated to the intern was the development of templates for the Visual Management Board, Standard Operation Procedure and analysing data for lean implementation. From the tasks allocated to the intern, are highlighted:

- Supporting the Senior Technical Team (Data gathering and processing, writing cell meeting notes).
- Designing and creating a set of KPIs and their monitoring.
- Creating Standard Operating procedures.
- Reviewing and creating new Load & Capacity studies.

1.3. Background and objectives

After projecting and designing the cell layout and its assembly, there was a need to optimize and to simplify the cell's functioning. In this project the optimization of a manufacturing cell is addressed.

The solution involved the application of Lean Manufacturing concepts and its tools, with the urge of reducing not only the waste, but also to prepare the cell to be scaled up in case of

increasing demand, as expected by the top management. Thus, the cell, and this way the company, is preparing itself to respond against the demand of the cone's production market in the future.

The main focus of this project was about the development and implementation of Standard Operations Procedures and Visual Management Boards as well. The goal was to standardize, organize and to set up activities to promote self-managing within the cell, while taking into account that all the templates created were suitable to future cells and also other departments across the company.

1.4. Thesis Structure

This dissertation has been divided into four main parts.

The first one, the introduction, contains the presentation of the project and also the presentation of the company where the internship was at. In addition, the motivations that led to this project are also addressed in this chapter.

The second main part is composed by the explanation of theoretical content. The purpose is to introduce the concept and philosophy of Lean Manufacturing and some of its tools to contextualize the reader into the project's subject.

After introducing Lean, the third part is presented. On this part, the project's subjects are presented, including the Standard Operations Procedures and the Visual Management Board's development.

At last, in the fourth main part of the document conclusions about the development and the results reached are presented, as recommendations for future steps as well.

2.Lean Manufacturing

2.1. Lean Origins

The concept of lean evolved from the management system of Toyota, known as Toyota Production System (TPS). This system was known as "a system of intertwined elements that might lead to competitive advantages" and it is identified for being the cause that led Japan to success after the Second World War in an attempt to reduce cost by producing in a continuous flow which didn't rely on long production cycles to be efficient. It is one of the most popular production concepts. It first appeared in the middle of the 20th century and led Toyota from deficit in 1951 through 60 years of profit to 2009 when the US car market fell due to the bursting of the US financial bubble. The TPS is quickly associated with the Just-In-Time (JIT) production but the cornerstone of the concept behind TPS is the "reduction of cost through the elimination of waste". Therefore, by using this philosophy, companies are able to eliminate waste, and for that reason, producing more efficiently and also gaining a competitive advantage [5-8].

The literature relates the Lean Manufacturing philosophy is closely associated to other philosophies such as World Class Manufacturing (WCM). These concepts are not exactly the same and they cover different domains. For example, Lean Manufacturing (LM) has considerable amount of overlap with WCM, the way to distinguish them is by analysing how they approach the same problems [5].

2.2. Principles of Lean Manufacturing

The word "lean" itself reveals the concept behind its philosophy, as lean manufacturing uses less of everything: uses half of the human effort in the factory, half of the manufacturing space, half of the investment in tools and half of the engineering hours to develop new products when compared to traditional mass production methods. More than a way of thinking, lean manufacturing "is a strategy to earn less input to achieve the organization's goals through producing better output". It's now important to define the definition of input and output. Input refers to the physical quantify of resources used and their costs, and output refers to the quality of the products sold and corresponding customer services [8].

There are other definitions too, for example that the essential aspect of lean is the efficient use of resources through the minimization of waste. Or that LM is no more than a tool to reduce waste and create wealth within the organization. The definition may vary according to the author but the main idea is that lean is about maximizing the costumer value while minimizing

waste by using tools that can help to increase productivity, enhance quality, shorten lead times, reduce cost, reducing setup times [8, 9].

Relativizing, lean can be understood by putting in perspective both the mass and craft production system against the lean system [10]:

- The mass production system, the one that we are more familiar with and is more recent in our memories, it is known for its push system philosophy. It uses the narrowly skilled professionals to design products made by unskilled operators.

- The craft production system uses highly skilled operators, and make use of simple and versatile tools. The downside is that this systems produces goods are highly expensive.

By contrast, the LM combines the best of both systems, without the expensive cost related to the craft system and the rigidity of the mass production system [10].

In sum, there are three main objectives in lean production [11]:

- First, is to achieve the highest customer satisfaction. This goal is accomplished by taking into account two aspects: to deliver customers products that respect the quality, functionality and price requirements which will lead to their satisfaction and to deliver the products on time in full, handing the requested demand with the right quantity on the agreed order delivery date.

- Second, the total elimination of waste, this requires to analyse each step in the production process and critically scan it to assure that each step the in process adds value from the costumer's perspective. Every single operation considered non added value to the customer is considered waste (or *muda* in Japanese) and actions should be taken to eliminate that waste.

- The third main objective is about the respect of human dignity in the production process. It is usual for the uninformed to think that LM is related to downsizing and layoff (temporary suspensions or permanent termination of employment of an employee or a group of employees for business reasons). Instead, lean manufacturers view their employees as valuable assets. It is expected from the employees to contribute for the continuous improvement, regardless of education or position. Although lean manufacturers seek to continue their production with minimal labour, the quality of the jobs tend to enhance both high wages and job security.

2.2.1. Structure of Lean Manufacturing

The structure of Lean Manufacturing can be decomposed in four major concepts – as illustrated in the Figure 1 – which, together, comprise an effective model for design, operation, and management of production processes [11].

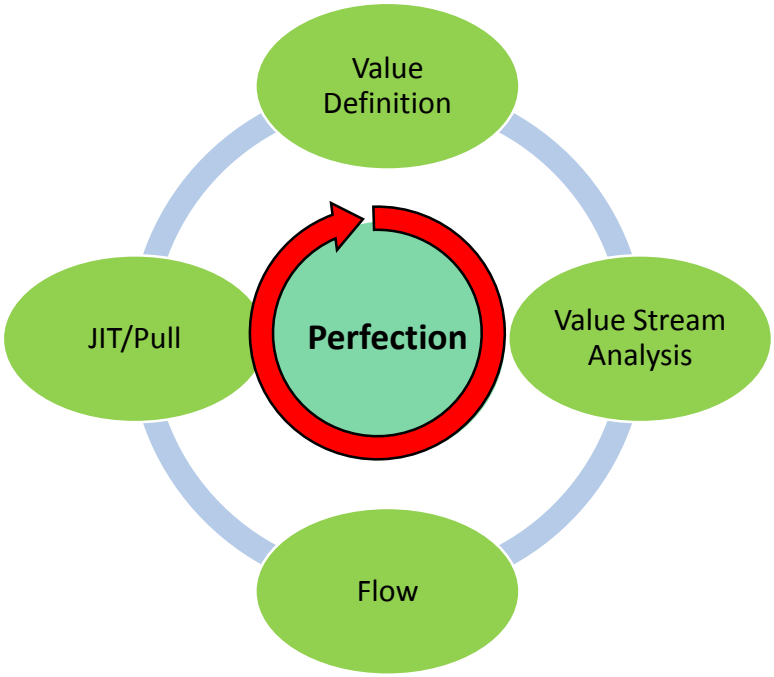


Figure 1 - Structure of Lean production [11].

2.1.1.1. Value Stream Analysis

When converting a conventional production line into a lean approach philosophy, the critical point lies on the definition and determination of value from the customer's perspective. It is good to remind that LM tends to seek only for activities that add value to the products from the customer's perspective. Whilst respecting the relationship between functionality, quality and delivery to meet their needs and desires [9, 11].

This kind of data requires extensive market research and the use of tools like Quality Function Deployment (QFD). Such a tool serves the purpose of helping to identify and to prioritize the customer needs and then translating the characteristics of those needs to specific design characteristics. The QFD can be broken down into four interconnected phases that will help to analyse the customer needs at the most basic level [9, 11, 12]:

- First phase, to translate customer needs into product design attributes.
- Second phase, to translate important technical measures into parts characteristics.

- Third phase, to translate important parts characteristics into process operations.

- Fourth phase, to translate key process operations into day to day production requirements.

The first phase, also known as HOQ (House of Quality), has strategic value in the QFD system analysis, since it is with this tool that the "voice of the customer" is transformed into requirements and technical information that is both useful and the key to develop an adequate production system for a specific output. Figure 2 is a representative 9-step model of a house of quality board. Where "HOW" stands for output and "WHAT" stands for input [12].

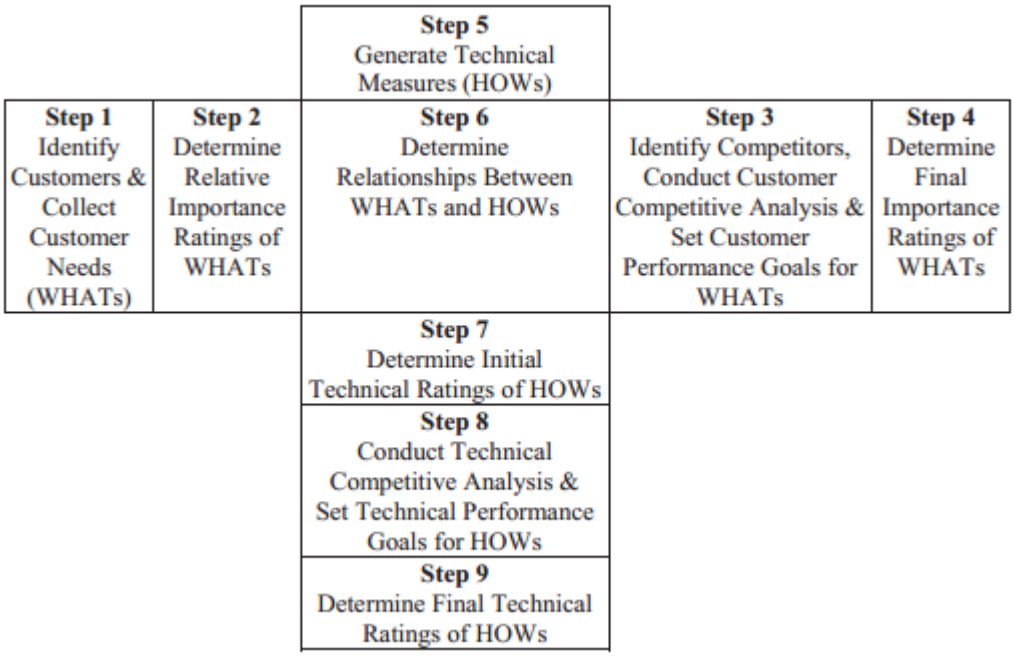


Figure 2 - House of quality (HOQ): a 9-step model [12].

The design of the product focuses on value that can be expressed as a ratio (benefit expected of a product attribute divided by the cost of that attribute). And using the principles of Value Engineering (VGE) – a systematic value to improve the value of the output by using an examination function – lean manufactures can focus in two indicators: high and low value product attributes. The first ones, the highest attributes, are great opportunities where low cost enhancements of product specifications can result in large gains for the organization. The low attributes are those who improve and innovate on the level of product design [11].

The foundation for value stream analysis relies on the definition of value. So the beginning of the value stream analysis begins with process mapping, which means to break down every single step of the process to make a specific output. This is a very important tool in LM, because it gives an overview of existing production and activities. Also, it identifies all procedures from the product development and design to production and the respective distribution

of finished product. With this tool, a map of the shopfloor or of the cell is drawn, enabling the visualisation of all the production processes and their interconnections [11].

The flow is one of the biggest cornerstones for a lean system. It may be expressed in two main goals that would be the ideal in a production system. They are [11]:

- Continuous flow, which means products should flow in a continuous way through value added operations without any delay.

- Levelled production, meaning the company should produce every product in the demand every day.

These goals are triggered thanks to both a direct and an indirect motivation. First, the direct one. For the direct motivation it is needed to develop a system that can respond effectively to the market demand. That way, the idea of continuous flow without delay suggests to operate with lead times as low as possible [11].

The lead time is the period of time between the start and the ending of a production process of a product. When the lead time is less than the customer's accorded waiting time, the need for the manufactories of make-to-stock is replaced by a make-to-order approach. For this to be accomplished is required to reach a level of equilibrium between the two ideals of flow, this way, avoiding wastes of overproduction [11, 13].

A more relevant motivation, the indirect one, is that the focus on flow stimulates perfection of the operations. To maintain a constant flow it is important to eliminate all WIP (Work In Progress) inventory, this way eliminating the associated wastes of inventory [11].

One of the key elements that help a company go lean is the cellular manufacturing. In fact, cellular manufacturing is an intrinsic concept of LM. A cell is a way of organizing the operators, the equipment and the workstation to benefit the process flow, by producing small batch or even a unit at a time [11, 13].

Producing with cellular manufacturing has implications such as[13]:

- Small batches, or one-piece flow.

- Often used for family of products.

- Personalized equipment for the cell.

- Usually the cell assumes the shape of a "U" or a "C".

- Skilled and semi-skilled operators.

Using cellular manufacturing has many advantages. One of the hidden and no so talked about benefits of a cell is the behaviour change of the operators. The cell brings the operators closer to each other, creating the feeling of a team. Believe it or not, the concept of team can be very strong and actually, cell might increase the synchronization between stations and so the equilibrium of the flow within the cell. Also, it might lead to the reduction of the cycle times. Most of the cellular manufacturing advantages are directly related to the seven wastes [13].

2.2.2. The seven wastes

Before start talking about the tools used to implement a lean system, it is important to define the goal of the implementation of lean manufacturing and it is only one: to reduce waste. This way, all efforts should go to flush out or reduce all the non-value added activities in every process of the organization. According to the literature, the waste can be categorized in different ways like [14, 15]:

- 3 "MU" (traditional Japanese approach).
- 4 M or 5 M (traditional Japanese TQM approach).
- Seven wastes (Japanese approach adapted by the USA).
    - Cost of poor quality (American TQM approach).

Waste is any activity in a chain of processes which does not add value to the costumer. Sometimes it is necessary in order for the processes to occur. For example financial control does not add any value to the costumer but adds value to the company instead [14, 15].

According to the Toyota Production System there are seven relevant types of waste within an organization. When talking about lean this is the most popular terminology, and is a good starting point to find the root causes of waste. The seven common wastes, also known as TIM-WOOD, are [15]:

- Transportation – unnecessary movement of products between processes.
- Inventory – raw materials, work in process (WIP) and finished products stored.
- Motion – unnecessary movement of the operators.

- Waiting – having to wait before commencing the next activity.

- Overproduction or asynchrony – producing too much, too early or too late to meet customer's demand.

- Over processing – processing beyond what the customer requires.

- Defectiveness – non-conforming products and services in general.

2.3. Tools and techniques

The lean thinking can be supported by countless tools and their variations with similar names. In fact there are researchers specialized in algorithms capable of identifying, characterizing and classifying the infinity of tools known as lean tools [16].

For example, in the Figure 3 is an example of a scheme created to facilitate the lean users picking the right tool for the right application. This concept helps the user to organize and to identify why and what type of tool does he need to select a tool. The tool works from the bottom to the top in the following steps [16]:

1. Application level - Define the tool's goal. If, for example, is it to measure, to identify or to eliminate waste.

2. Characteristic level – The motive that led to pick a tool. For example: poor morality, incapability, inefficiency or unreliability.

3. Activity level – to select if the tool is going to be used by the management or during the period of time, on the shopfloor for example.

4. Operation level – to select the right tool according to the type of operation, being for example, processing or storage.

5. Object level – to select the type of goods in question. For example raw materials, WIP or finished goods.

6. System level – to identify the type of infrastructure the tool should cover.

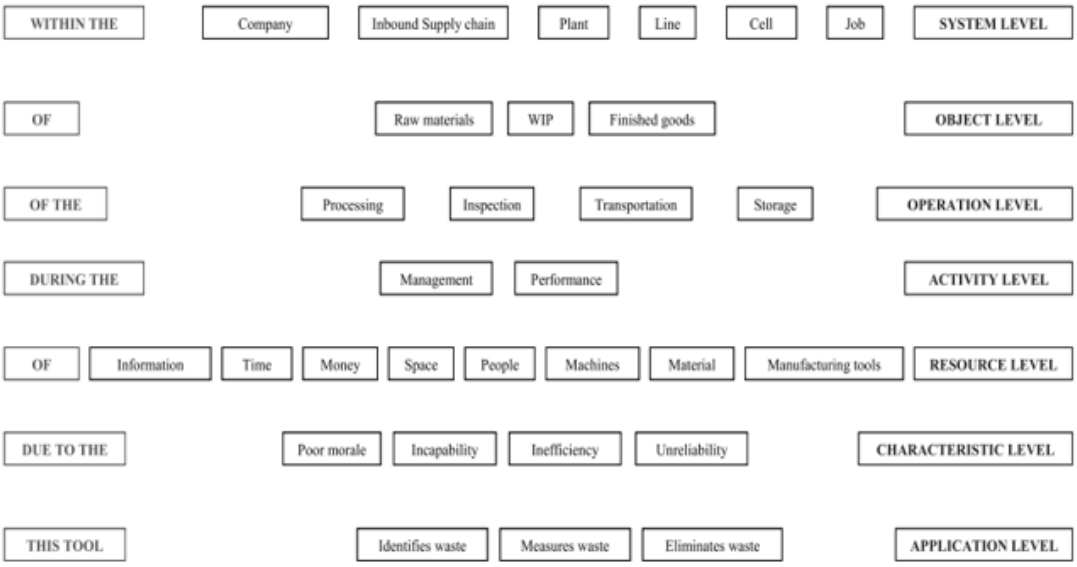


Figure 3 - Classification scheme for Lean Manufacturing [16].

2.3.1. Standard Operation Procedure

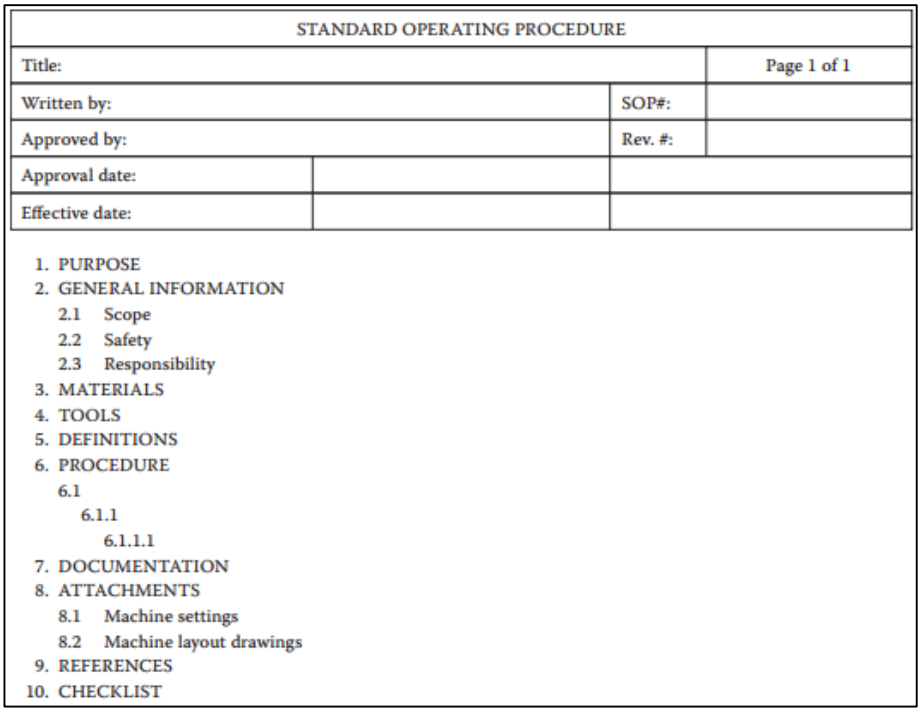
The standardized work is a concept which is part of the TPS philosophy, and not just a format for document of work. Therefore, the standardized work expresses the best known way to complete a task in the most efficient way possible meting the quality requirement levels. However, in lean manufacturing it cannot be really assumed that a certain process is at its best performance, because the goal is to constantly seek for continuous improvement opportunities, *kaizen* (Japanese word for improvement). Due to this constant drive for improvement, it can only be assumed that standardized work is not permanent. Hence it is possible to redefine the standardized work as being the currently best known method to complete the work [17].

Being aware of the concept of standardized work allow us to understand the need of creating a document that helps to establish a standard across the company, the Standard Operation Procedure (SOP). This document can be created in many different ways, it can be in a text form, pictorial or even in flow chart form. It might be also known with different names such as: standard operations instructions for example. Nevertheless, the objective is to properly help the operator with the changeover. This way, the SOP should be clear enough so the operator with little or no skill can accomplish the work successfully [17, 18].

Therefore, the SOP should describe step by step the procedure, so that the operators knows he has have to do in order to complete the job according to the standards. The instructions in the SOP must be clear for the operators, to ensure a complete understanding of the work. Also, the instructions need to be broken down in small steps to cover the details of the work and making them simple to understand and to follow [19].

The investigation phase, where the process is studied by the engineers, so they can break and write down all the steps of the process, is a good opportunity to think and rethink about the process, because the exercise of breaking the process in small tasks might allow the engineers to reflect about the process and find another way, a better one, of completing a certain task. Also, the SOP may help solving future problems by making the task of finding the root cause easier, because it can work as a reference document to conduct investigations [17, 19].

To begin the implementation of SOPs, in they are not applied in other parts of the facilities, the company needs to create a template. The template should fill the needs of the company, so it should be adequate to the type of sector, for example. It may make sense to implement a text form SOP in a call-centre. But it may be more suitable for a factory to implement an SOP with a more visual appealing on the shopfloor. The Figure 4 represents an example of a template, with the main subjects a SOP should have [18].



STANDARD OPERATING PROCEDURE			
Title:			Page 1 of 1
Written by:		SOP#:	
Approved by:		Rev. #:	
Approval date:			
Effective date:			

1. PURPOSE
2. GENERAL INFORMATION
   - 2.1 Scope
   - 2.2 Safety
   - 2.3 Responsibility
3. MATERIALS
4. TOOLS
5. DEFINITIONS
6. PROCEDURE
   - 6.1
     - 6.1.1
       - 6.1.1.1
7. DOCUMENTATION
8. ATTACHMENTS
   - 8.1 Machine settings
   - 8.2 Machine layout drawings
9. REFERENCES
10. CHECKLIST

Figure 4 - Example of an SOP template [18].

In the header of the SOP are some relevant points: the revision number (Rev. #) and the “approved by” fields. The revision number informs about how many times the document has been reviewed. Since the process might be suffering little changes due to the continuous improvement, it is important to maintain the SOP up to date so it matches the changes in the process that might affect the course of the work. The “approved by” field corresponds to the name of the employee that approved the SOP. So it is important to have someone responsible for the approval of the changes on a certain SOP, before putting it to use. That approval process

must be done by someone not only with technical knowledge to evaluate the changes, but also by someone with a sense of organization and readability [18].

Implementing SOPs in a company can be a tricky task, especially when the number of processes covered by the SOPs is high. So it is important to stick to the template first created, in order to set up a standard so it passes a feeling of organization across the company. Is also important to cover the important information in the first pages so you can quickly identify if is this the specific SOP first wanted to read, giving us the first insight of the document without needing to read it completely [18].

For these reasons, the first insight of the SOP can be given by introducing: the title, that should be descriptive but brief; the purpose, where a statement should be made telling what is wanted to achieve with the SOP and it should be no longer than two to three sentences; and the scope, where it is described what precisely is covered on the SOP [18];

In some cases, due to the type of process the company is running it might be interesting to add chapters to inform about material and tools. These chapters inform the reader about the materials and/or tools needed for the completion of the task, such as: cleaning supplies and machine parts for a changeover for example; or tools like screwdrivers or gauges the operators will need. This way, it is possible to prevent missing materials or tools essential for the work to be completed, preventing waste of time, motion, or even non-conformances [18].

The most important part of the SOP is the procedure, since it is the purpose of the document. Although SOPs may cover really complex processes, its instructions must be broken down and expressed in a simple way, which can be a challenge when heavy engineering is involved because every single person attached to the process must be able to understand it. Besides instructions from the SOPs should be extremely accurate and described in detail exactly what it needs to be done, so nothing is left for the operator to decide, restraining ambiguity [18, 19].

At last, the check list is sometimes misinterpreted as SOP. The checklist is a list of items required or tasks to be complete, but the difference is that the checklist is an abbreviated version of the SOP's instructions, so it works as a complement of it. For instance, a really complex and most of all extensive procedure might have an SOP with several pages, as normally it is not reasonable to expect that such extensive document will be used on a daily basis. Besides that, with time comes experience, so it is normal for the operators to learn the process and this is where checklists can be important, because they are not as extensive as SOPs are. Also, when a procedure is performed just by memory a deviation from the procedure's instructions is expected, this way, a compact document will assure the operators are not skipping any step from the SOP, or work as a reminder for them [18].

2.3.2. Overall Equipment Effectiveness

The Overall Equipment Effectiveness (OEE) is a helpful tool. Its function is to identify, in a general form, the major losses in equipment performance and its reliability. So it makes it one of the most important maintenance metrics in the field. For that matter, this metric comprehends together equipment, process, material and people. This metric can be calculated by multiplying three variables: availability, performance rate and quality rate – Figure 5 [17, 20].

$$Performance = \frac{Ideal\ Cycle\ Time}{\frac{Operating\ time}{Total\ Pieces}}$$

$$Availability = \frac{Operating\ Time}{Planned\ Production\ Time}$$

$$Quality = \frac{Good\ Pieces}{Total\ Pieces}$$

$$OEE = Availibility * Performance * Quality$$

Figure 5 – Formulas for the calculus of the OEE [21].

Altogether there are four main parameters to calculate the OEE, as the Figure 5 shows [13, 21]:

1. Cycle time. This parameter represents the achievable amount of time needed to complete the process in the most efficient way known.

2. Operating time – Equation 1. It represents the amount of time the facility is open and available to operate and is the result of subtracting the downtime loss from the planned production time – these two last variables are addressed below.

$$Operatin\ Time = Planned\ Production\ Time - Downtime\ Loss \quad \text{[Eq. 1]}$$

2.1. Downtime loss – Equation 2. This parameter includes any events that had stopped the production in such time it is possible to log them as a trackable event. One example of Downtime loss would be the changeover, or set up. But also can be material shortages and equipment failures.

$$Downtime\ Loss = \sum [Stopping\ Trackable\ Events] \quad \text{[Eq. 2]}$$

3. Planned production time – see Equation 1. It represents the amount of time given to activities that are not operating time and are planned (breaks, lunch, maintenance, periods of time where there are no production planned).

3. Total production, including the scrap parts – also called total pieces as shown in Figure 5.

4. Quality products, in other words, the saleable ones.

The OEE is calculated to analyse as an all but it is also important to analyse and understand the variables and how misleading the OEE might be if not well known, more importantly while in the early stages of implementing lean in a process. The OEE can assume values between 0 and 100%, and the reasons that keep the OEE under 100% are the losses. Being said, there are different types of losses in each parcel of the OEE. In the Figure 6 there is a scheme of the different types of the existing losses and where they fit [20].

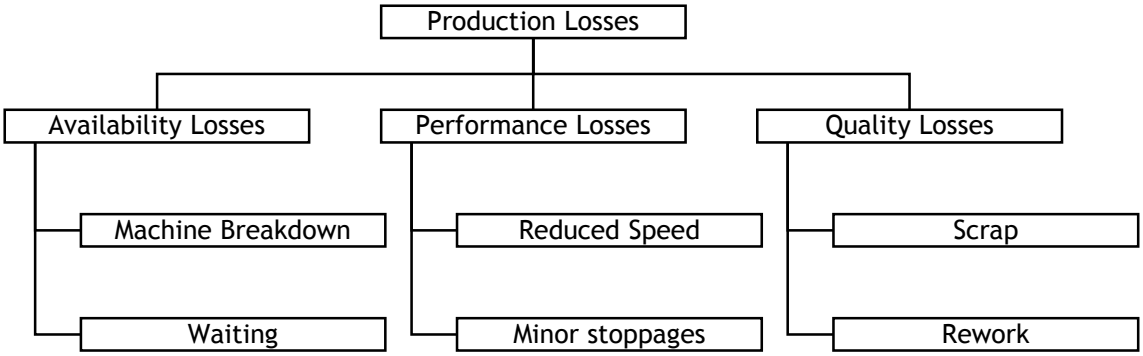


Figure 6 – The six big losses [20].

The availability is a ratio affected by the downtime loss described above. The availability loss is the amount of time the machines are stopped when they should be operating and producing. Availability losses may be considered any machine breakdown (tooling failures, unplanned maintenance, equipment failure) or waiting (setups, major adjustments, and material or operator shortages). This way, a 100% availability rate means the process runs without any stoppages [20-22].

The performance rate takes the speed loss into account. The speed loss are variables that make impossible for the process to run at its full speed. Usually any stoppages that are under five minutes are considered a speed loss, and not a downtime loss. Since it is hard to track this small stoppages, the speed loss can be taken into account by comparing the ideal cycle times

with the current cycles that are being calculated. This way, 100% performance rate means the process is running at the ideal rate without stumble [21].

The quality rate is affected by the quality loss. The quality loss is more often analysed through the ratio between the scrap and total produced parts. This way, 100% quality rate means the process is running without any scrap parts or reworks [21].

Because the OEE is the combination of three factors each one considering three different losses, it is important to look at the OEE in a further level. By analysing the OEE factors individually it is possible to identify what type of loss affects the OEE. For instance, a low availability means the process is unstable and is associated with failures on the machines or materials issues. When the reason for a low OEE is the performance rate then this parameter can be simply improved by focusing the resources on the variation causes and establishing standardized work [13, 21].

The generally accepted World-Class goals of the OEE for each factor differ from each other, as show on the Table 1. At the end is expected the OEE to be superior to 85,0% in order to be considered as World-Class manufacturers, while the average OEE is 60%. Figure 7 represents the results from a study done with 725 consumer packaged goods manufacturing operations around the world in 2009, the data obtained show where the companies fit in terms of the OEE, classifying them as: best of the best, best in class (top 25%), middle (50%) and laggards. This kind of studies allow the companies to know where they fit and how far or not are they from reaching their goals, whether is to be a middle or a best class [21, 22].

Also, it might be helpful and more insightful to analyse the variation of the OEE according to the type of industry. In the Figure 8, it is possible to conclude the medical devices industry is the sector, in this study, with the biggest OEE average. On the other side, the aerospace and defence and the semiconductor industry have the lowest averages for the OEE, amongst other industries presented on the chart.

Table 1 - World Class goals for the OEE factors [21].

OEE Factor	World Class
Availability	90,0%
Performance	95,0%
Quality	99,9%
Overall OEE	**85,0%**

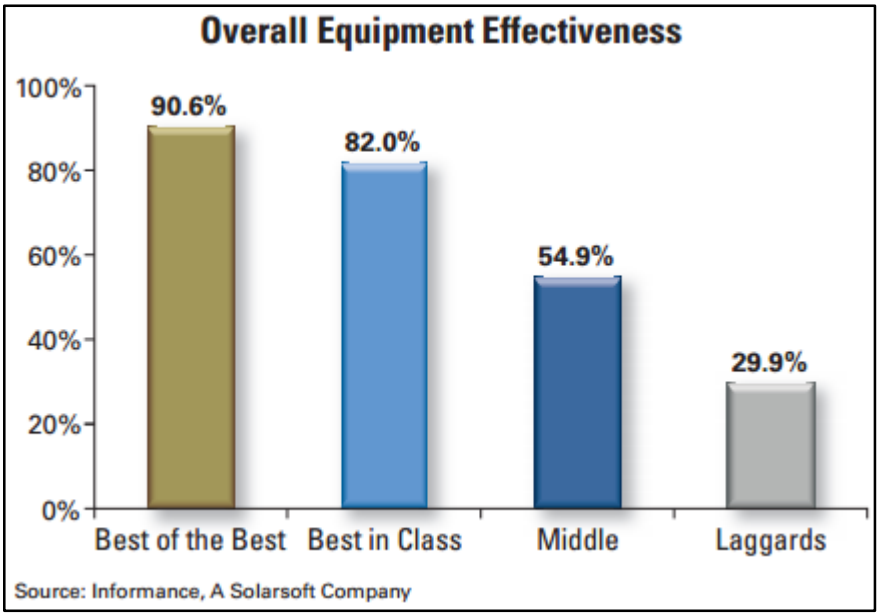


Figure 7 - Benchmark values for the OEE [23].

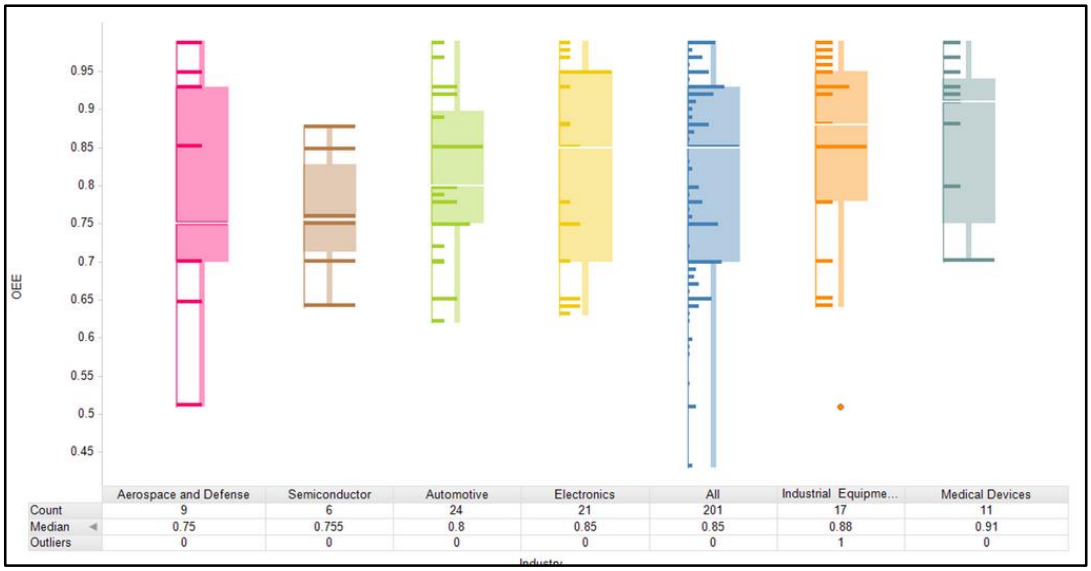


Figure 8 - Overall equipment effectiveness histogram and box plot.

3.Practical case

3.1. Cell Layout

As said, the cell production project is under its fourth phase. At this stage the goal was to optimize de the cell and to implement LM in it.

In previous phases one of the goals was to design an efficient layout for the cell. In order to get to the actual cell – represent in the Figure 9 -, studies were made. These studies were carried out with the use of lean tools, such as spaghetti diagrams and the seven wastes, for example.

With the knowledge of the process plus the information extracted for the use of such tools. It was possible to come up with a layout that combines the most efficient way and at the same time minimizes the waste.

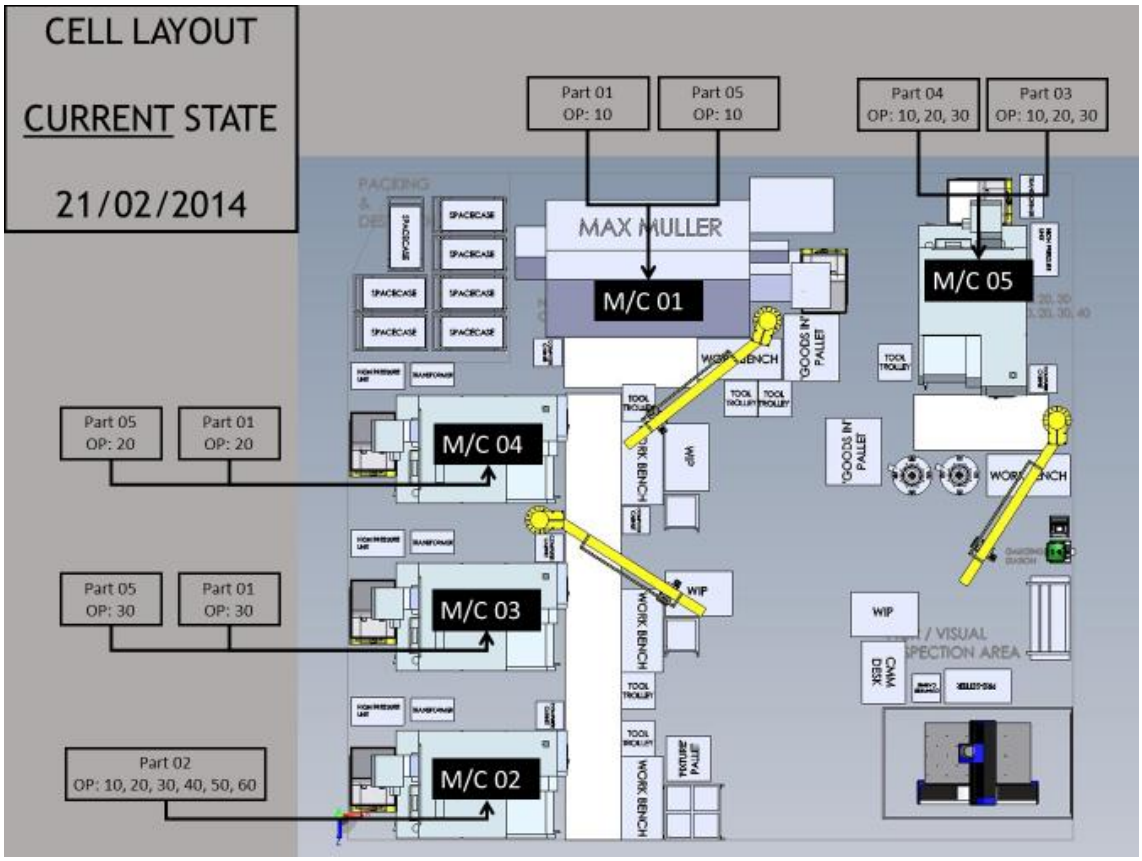


Figure 9 - Cell Layout.

3.2. Standard Operation Procedures

In order to set up a standard across the cell in terms of procedure and conduct for the operators, a template was made. With the creation of the SOPs for the cell, the goal is to lead the operators to work within by specific design procedures. Therefore, the company expects to eliminate human error minimizing variation through instructions necessary for the operators to deliver conformance products.

Although the instructions in the SOP are not extremely detailed, it is not a simplified document without relevant information. During the development of this document, it was discussed about how detailed this document should be. Despite the SOPs are meant to be a document when read you should be capable of accomplishing the goal without having the know-how, it was realized that definition would not fit our purposes.

Therefore, it was concluded that because the operators, in order to operate the machine, have the know-how to use such equipment, in other words they are skilled, there is no need for the SOPs to be extremely detailed. In fact, that could cause some problems, such as: turning the SOP in an extensive document difficult to read and to consult; distracting the operator with several needless instructions preventing them from focusing on the key tasks of their jobs. For this matter, during the development of these documents it was reached an agreement about the level of detail it should put in the SOP accordingly to task difficulty or how critic a certain task can be in order to not compromise the quality of the part.

The Figure 10 is the front page of the first SOP made with the new company's template. It was decided to include on the first page the following information:

- The department, so the user knows to which department is responsible for this SOP.
- The title, acknowledging the user the resumed purpose of the SOP.
- The document number. With this new template each SOP done will have its unique identification number with the following concept: the first three letters are an acronym for "Castle Precision Engineering"; the following four letters will describe the department responsible for the SOP (production, quality, finance, maintenance, etc.); the last four digits represent the unique number of the SOP in the company. This way if after the CPREPROD0001 the next SOP is from the quality department, it would be called CPEQUAL0002.
- The document version – which will be addressed and explained further when the second page is introduced.

- Initial Release Date, which indicates the date when the SOP was issued.

- Last Revised Date, which informs when was the last time the SOP was revised.

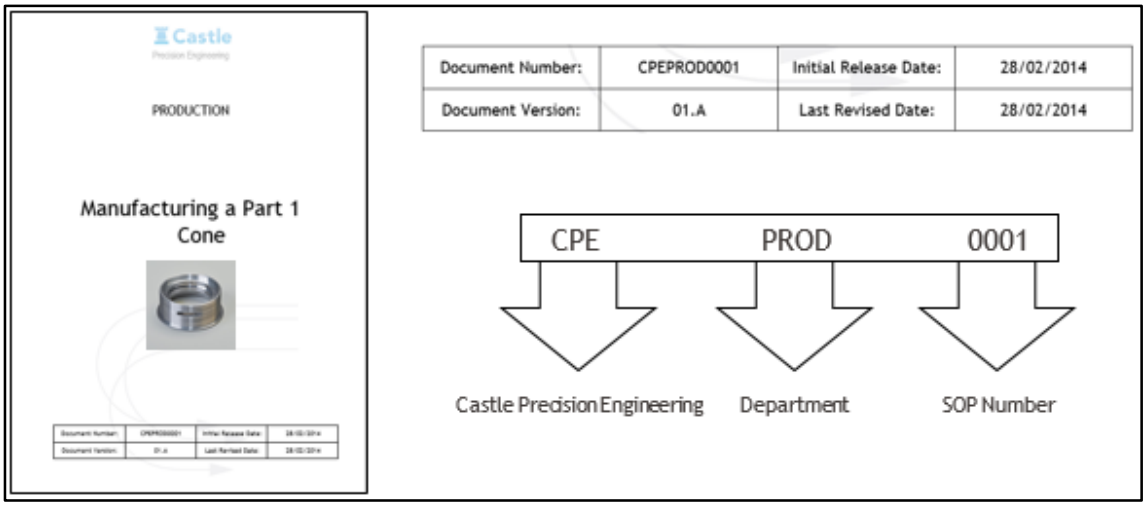


Figure 10 – On the left is the front page of the "Manufacturing a Part 1 Cone" SOP made with the new template, and on the right is the same footer of the front page zoomed in. Plus a scheme explaining the SOPs coded name.

The next part - in Figure 11 - is dedicated to the following:

- Purpose, to ensure a standardized approach is adopted whilst a manufacturing a certain part on a certain machine.

- Scope, to inform about the type of action covered by the SOP.

- Responsibility, to inform who is responsible for the activities of the procedure on the SOP.

- Definitions, to establish abbreviations and acronyms used in this SOP.

- Reference documents that can be helpful for the activities.

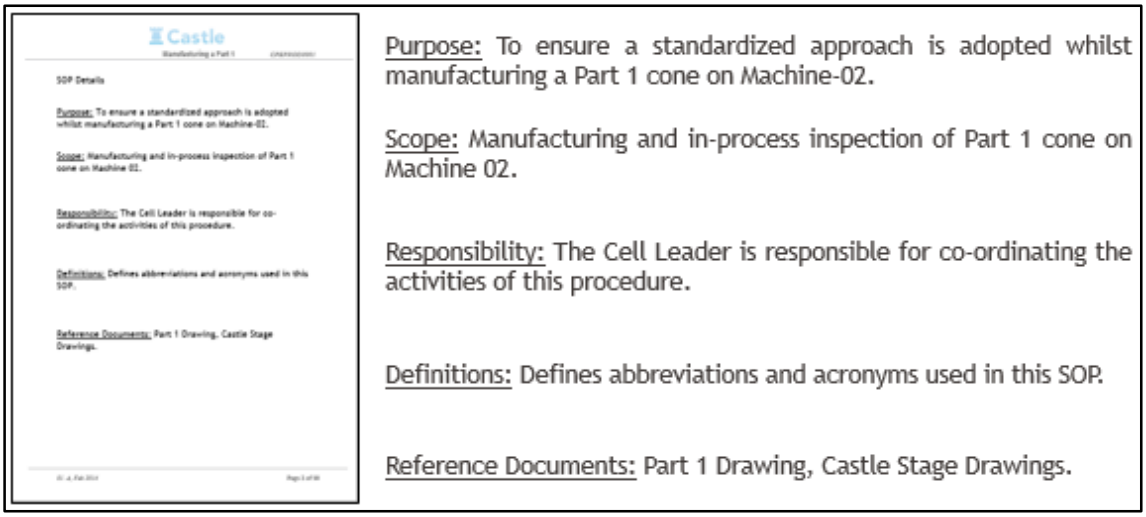


Figure 11 – On the left is the second page of the "Manufacturing a Part 1 Cone" SOP and on the right there is the content of the page zoomed in.

The following part of the SOP is dedicated to the history of the SOP. The company will be able to track every step on the SOP's history. Having access to information, such as when and by whom the document was created. Also, access who did the following reviews and modifications, as represented in the Figure 12.

The page begins with a table where it is possible to keep track of the changes of the SOP. The first column, "Page No.", is where the pages that suffered changes are tracked. For example on the example showed in the Figure 12, it is possible to read "all" on the first column and first line, because this is when the document was introduced into the system. From there, when changes that don't involve all the pages in the document are done then the modified pages should be mentioned in this column.

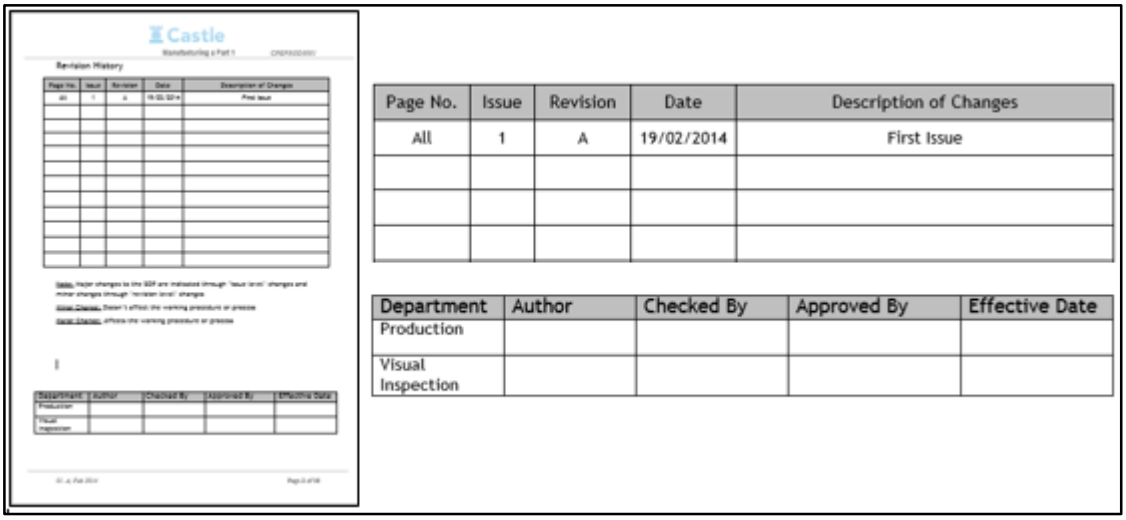
It was established that two different types of changes on the SOP should be distinguished in two different types:

- Major changes that have a considerable impact in the process procedure should be labelled as "issue level" changes.

- Minor changes that have a low or no impact in the process procedure should be labelled as revision level changes.

For these reasons the second and third column are there to keep track of the major and minor changes. The first one is counted with digits and the second one with letters. The last two columns are self-explanatory, the date column serves the purpose of tracking when were the changes made on the SOP and the "Description of Changes" column gives a general resume of the changes made.

The bottom table at the footer informs about which department is responsible for the SOP, who does the changes and also who checks and approves the changes. The last column is about the effective date, in other words, the date the procedure started being used.



Page No.	Issue	Revision	Date	Description of Changes
All	1	A	19/02/2014	First Issue

Department	Author	Checked By	Approved By	Effective Date
Production				
Visual Inspection				

Figure 12 – On the left is the third page of the "Manufacturing a Part 1 Cone" SOP and on the right there is the content of the page zoomed in.

Inside each SOP is a flow map of the process. With this tool it is possible to follow the steps of the process in order to achieve the final product. When the process is extensive it is easy to lose focus, this way a flow map, here in Figure 13, can be very useful to see the big picture.

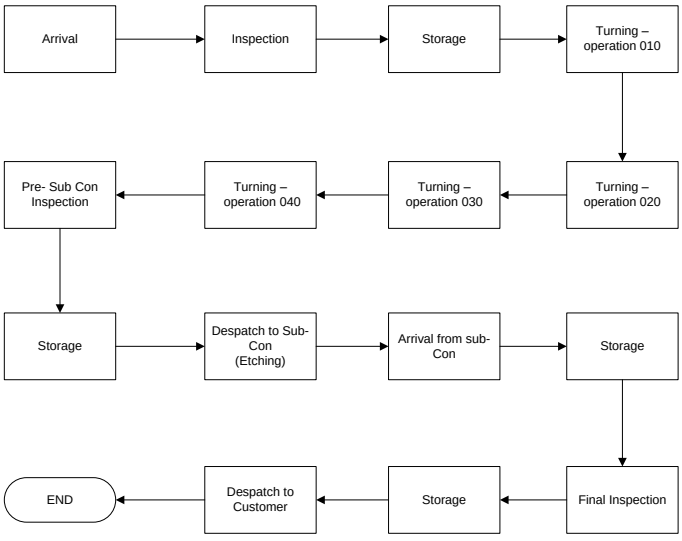


Figure 13 – Flow map of the process shown on the "Manufacturing a Part 1 Cone" SOP.

The next part of the SOP is a simple presentation of the content within the document – possible to analyse on the Appendix A.

The following pages of the SOP consist on the instructions of the process. This is the most important part of the document for operators to read and use. The instructions were written

in a very simple way and in the clearest form possible, leading them to be error proof. Whenever needed, pictures were added to the document. It was important to illustrate because the use of visual literacy in this kind of instructions give strength to the textual message, increasing the chances for the operator to fully understand the message within the instructions.

In order to make this document possible, there had to be research in the shopfloor. This way, during the production time notes were written down alongside with an experienced operator. At the end the notes taken were put against the notes from the operator. The next step was to transcript what was observed in clear and simple sentences, so everyone across the company could understand. Putting the notes from the two different perspectives together allowed the team to build a solid document, where the clear instructions are not too extensive and are specific and improve the process by turning it more error proof.

An example of the visual literacy is shown both in the Figure 14 and Figure 15. It is possible to see the pictures illustrating the main message of each instruction, plus some bits were highlighted in order to demonstrate the subject mentioned on the instructions.

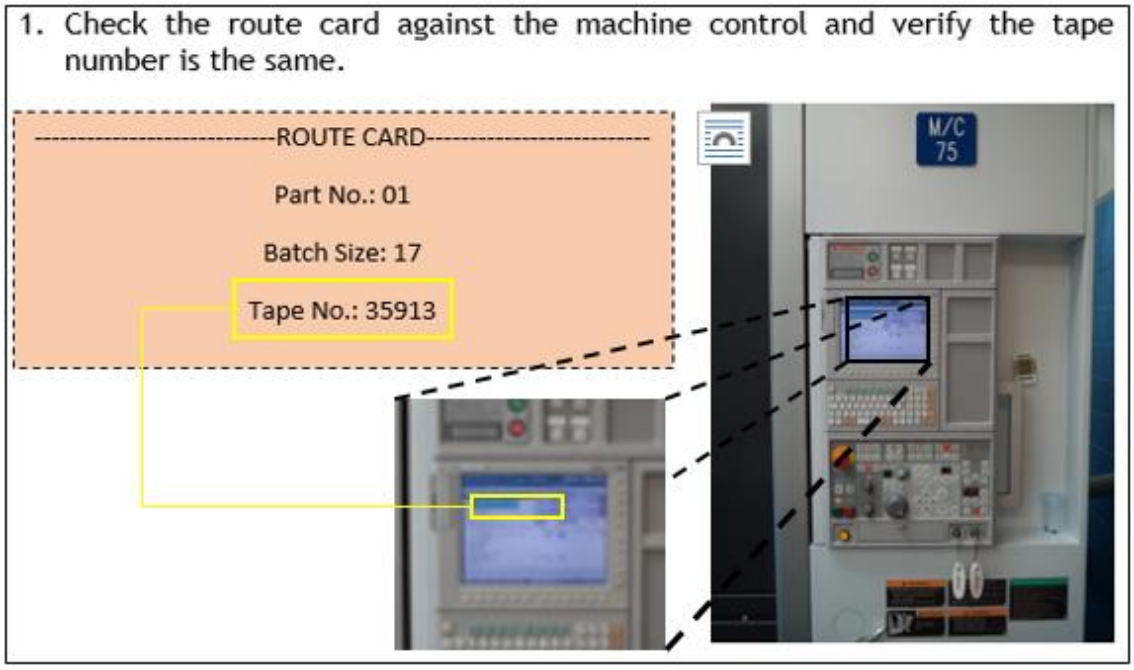


Figure 14 – Example of an illustrated instruction. Here, is clear the need to verify the matching between the tape on the route card against the computer.

3. Clean down fixture & clean the screw holes from the previous fixtures with the help of a compressed air gun.

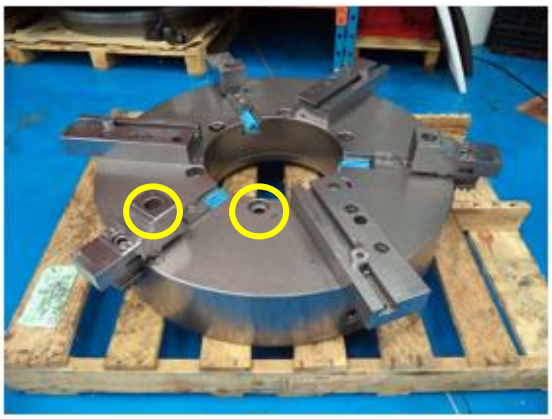


Figure 15 - Example of an illustrated instruction. Here, is clear the need to clean the holes where the next fixture from the next operation will be attached.

As mention above, the team found no need for the SOPs instructions to be extensive and overly descriptive. In the Figure 15 is an excerpt of the instructions, and is possible to conclude the instructions are written in a simple way.

For instance, the instruction number five says “to ensure correct location”. At first sight this can be ambiguous, but since no operator goes to a machine without going for a period of learning (not only interacting with machine but also machining the specific component on a specific operation), there is no need to extend the content of the instruction with something the operator must know to be responsible for that specific task on the first place.

In the other hand, there are instructions that are quantitative and consequently not are ambiguous at all. Actually, it was made sure some critical points were bullet proof. For example, on the instruction number nine it is asked to the operators to position the clamps in the right position (like the last example this sentence is quite ambiguous). However, on the same instruction it is said “tighten them to 40Nm”, an important variable to be controlled in order to assure perfect attachment and compression. This way, it is possible to make sure the first part of the sentence is not overlooked, while making sure the critical point of this instruction is highlighted.

4. Put in grub screws to protect the screw holes of the previous OP fixture.
5. Remove grub screws from OP 10 clamp's positions to ensure correct location of OP10 fixture and the component before the start of the cycle.
6. Remove the forging from the trolley and place it on the workbench and check the serial number to ensure the paper-work is correct (part marking and ticket match).
7. Clean the forging to remove any soil or FOD that could compromise the quality of the component and inspect forging for damage.
8. Place the forging on the main fixture & check with feeler gauge to ensure component is located correctly on the fixture.
9. Place OP10 clamps in their respective positions and tighten them to 40Nm to ensure the component is secured.

Figure 16 – Excerpt of the instructions from four to nine of the "Manufacturing a Part 1 Cone" SOP.

For the production department SOPs, for each operations instructions chapter there is an appendix with the tooling needed to complete the operation. In every appendix is possible to see a table – see Table 2 - for each tool/insert pair. Inside each table there are: a tool number, a tool description, an insert description, a tool colour code, a picture of the tool and a picture of the insert. Again, is possible to observe the recurrent drive to apply the visual literacy, in this case, to make the operators select the right tools for the operation and also, to put them in the right station inside the machine.

Table 2 – Excerpt of the SOP.

Tool No.	T0519 [Station Number, Off set number	
Tool Description	ABC1234*	
Insert Description	CNMG 190612*	
Tool Colour Code	Purple	

3.3. Development of the Visual Management Board

One of the main goals of this internship was to create and to design several templates to set up the visual management board of the cell. While doing this, the objective was to set up a standard to the company.

With the implementation of the visual management board at the cell, everyone who goes to the shopfloor may be able to be updated of the most recent events in cell. In order to that, there are several KPIs integrated in the board, with them the reader must understand how well or not is the cell working.

The Figure 17 shows the first version of the visual management board. In fact, it is only a draft since the templates were not developed at that time, and to represent them they had put green squares to preview where they wanted the boards to be. There are several subjects addressed in this board, and some of them suffered changes, were deleted or added in the second version of the visual management board - Figure 18 . To compare the subjects present in each version check Table 3.

In this subchapter the subjects not address in the subchapters below will be shortly reviewed.

The Kamishibai Boards, literally a board with green and red signs are planned to be used further in the future. These boards are going to help the cell leader to do his daily tasks. For that, a list of standard task to be followed by the cell leader has been put together.

It is also important to say that the cell leader is going to be a rotative role within the cell. Each time an operator is meant to be at the cell leader he has certain tasks to do, one of them is to keep the visual management boar up to date. This role is one of the five roles addressed on the Operator Rota System board. This board will inform of when the operators will be in charge of a certain tasks, there are five different roles:

- Cell Leader
- H&S Champion
- 5S Champion
- Energy Champion
- Continuous Improvement Champion

- The schedule pattern is a board where the average batch per weeks is posted.

The SQDCP is a group of five boards that require daily maintenance. The idea is simple. If any non-conformity on that day happens then that exact day should be marked as red on the respective board. For example if any scrap parts is produce then the day that happen should be marked as red on the Quality board. If everything goes well then at the end of the day or at the beginning of the following day it should be marked as green.

The number of days since the last accident board is quite simple. It displays the number of days since the cell had an incident.

The cone production escalation map is in the visual management board as informative. It tells the hierarchy of the several positions of the cell. It can be useful in several occasions. For instance, if a machine fails then on the escalation map is possible to consult who is responsible for the maintenance within the cell team.

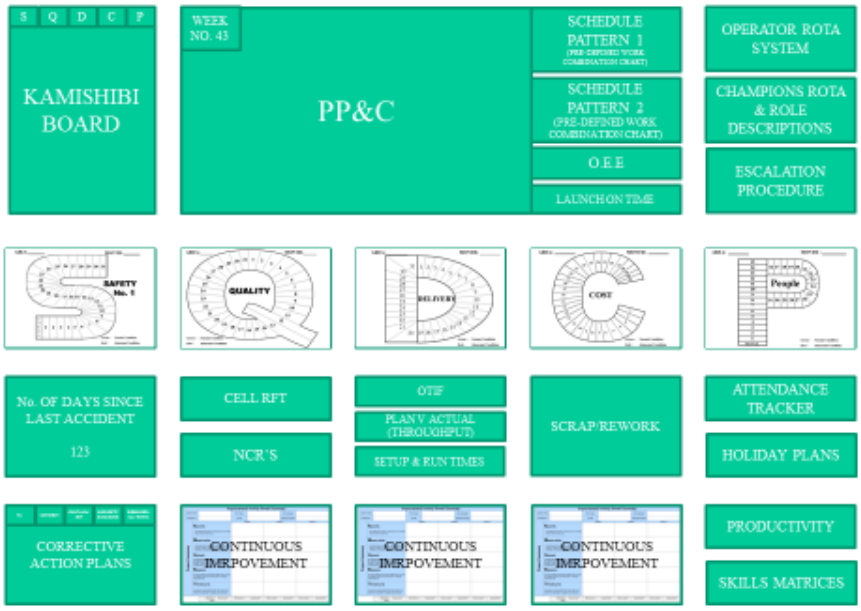


Figure 17 - First version of the Visual Management Board.



Figure 18 - Second version of the Visual Management Board.

Table 3 – Subjects addressed in the Visual Management Boards of the 1st and 2nd version.

1st Version	**2nd Version**
Kamishibai Boards	Kamishibai Boards
PP & C – Planning Production & Control	PP & C – Planning Production & Control
Schedule Pattern 1 and 2	Schedule Pattern 1 and 2
OEE	OEE
Launch on Time	Launch on Time
Operator Rota System	Operator Rota System
Escalation Procedure	
SQDCP – Security, Quality, Delivery, Cost and People	SQDCP – Security, Quality, Delivery, Cost and People
No. of days since the last accident	No. of days since the last accident
Cell RFT	Cell RFT
NCR	
OTIF	OTIF
Plan Versus Actual	
Set Up and Run Times	
Scrap & Reworks	Scrap & Reworks
Attendance Tracker	Attendance Tracker
Holiday Plans	Holiday Plans
Productivity	Productivity
Skills Matrix	Skill Matrix
	Cone Production Cell Escalation Map
	Cell Layout

3.3.1. Overall equipment effectiveness

The OEE is not currently being used at the company. One of the goals of the project was to develop a template where the OEE could be tracked down. What was done was a tool where it is possible to track down and to calculate it. An effort was made to optimise and simplify the task for the users. Using the tool it will not take too much time for the operators. By making it simple is less probable to make errors during the calculation of the OEE.

This tool was developed using Microsoft Excel. At the end the file is composed by several tabs all linked with each other. Together they compile the data and present them by different levels of specificity. The tabs are composed by: calculator, data and chart tabs times the months of the year, OEE summary and OEE management board.

For each machine on the cell was done one personalized calculator. This way the operator only needs to populate the calculator with some simple data to obtain the OEE. In the Figure 19 is an excerpt of the calculator for the machine 01 and 02. It was established that the OEE would be calculated by machine. Tracking the OEE by machine will allow to identify bottlenecks at the cell.

As shown in the Figure 19, inside each calculator is represented which part is being produced there and also which operation. This is important to calculations because different parts and operations have different cycle times. Having a row for each operation frees the operator from worry about the cycle times.

Machine 01

Part No.	Planned Production Time	Schedule Downtime	Setup	Unschedule Downtime	Operating Time	Operation	Cycle time	Total Production	Rejects	Availability	Performance	Quality	OEE
Part 1													
Part 5													
									Average				

Machine 02

Part No.	Planned Production Time	Schedule Downtime	Setup	Unschedule Downtime	Operating Time	Operation	Cycle time	Total Production	Rejects	Availability	Performance	Quality	OEE
Part 4													
									Average				

Figure 19 - Excerpt from the calculators for the machines 01 and 02 from the calculator tab.

In order to obtain the OEE for the machines, it is only asked for the operators to populate the calculator with five variables of each part, the white cells:

- Planned production time.
- Scheduled downtime.
- Unscheduled downtime.

- Total production.

- Number of rejects.

The other grey cells to fill, must be filled by a foreman or someone else responsible for the production, also the grey cells are protected so they can only be edited by knowing a password. Some grey cells contain formulas so they don't need to be filled because values will display while populating the calculator white cells.

In order to test the developed tool it was carried out a trial with the available data at the moment. Since the process is still unstable and suffering changes almost in a weekly basis, some aspects had to be assumed taking into account the opinion of members from the team. The following explanations of how the tool was developed are illustrated with an example. The part chosen was the part 4. Also the data chosen to be part of this example is coming from cell method works order.

The first column of the calculator is the name of the part. The second column is the planned production time. At the company each day of production is previously planned by the foreman. Each foreman is responsible for each section of the shopfloor. The cell studied is in the turning area, so the foreman responsible for the turning sector is going to plan the production for each machine and allocate the necessary operators.

Taking into account this information it was assumed that the planned production time for this example would be the sum of the run cycle time times the total production, plus the setup for the operation. In the Figure 20 is represented the calculator of the OEE for the machine 02 where is possible to verify the planned production time is related both to the cycle times and total production.

Machine 02

Part No.	Planned Production Time	Schedule Downtime	Setup	Unschedule Downtime	Operating Time	Operation	Cycle time	Total Production	Rejects	Availability	Performance	Quality	OEE
Part 4	660	15	20		625	10	30	16		94,7%	76,8%	100,0%	72,7%
	580	15	20		545	20	25	16		94,0%	73,4%	100,0%	69,0%
	660	15	20		625	30	30	16	1	94,7%	76,8%	93,8%	68,2%
	740	15	20		705	40	35	16		95,3%	79,4%	100,0%	75,7%
	980	15	20		945	50	50	16		96,4%	84,7%	100,0%	81,6%
	660	15	20		625	60	30	16		94,7%	76,8%	100,0%	72,7%
									Average	95,0%	78,0%	99,0%	73,3%

Figure 20 - Machine 02 OEE calculator.

Fifteen minutes was assumed for the schedule downtime. Fearing to affect negatively the results, since there were no track of the unscheduled downtime so far it was decided not to populate this column.

The following column, total production, needs to be populated taking in to account the length of time to track the OEE. It can be tracked in a daily basis or in a weekly basis for example

(analysing the Figure 20, this example is calculating the OEE of the machine 02 for a week). Either way, the operator responsible to use the calculator must be aware of such information. In this case, the part 4 has a current weekly demand of 16 parts.

The last white column is where the rejects are counted, so every part produced in the machine that did not fulfil the clients' requirements count as a reject.

The setup and cycle time columns are not meant for the users to edit as said before. The setup column was established to assume twenty minutes for each operation. This happens because the times for the cell method setup will be known when the videos from the Value and Non Value Added (VA NVA) study are completed. The cell method cycle times are already known thanks for the VA NVA videos.

The operating time column has a formula in it – showed in the Equation 3. First of all, in almost every cell it was used the function "IF" in order to make the cells with formulas in it to return a blank space when there is no data populated on the cells within the formula. The following acronyms stand for:

- PPT, Planned Production Time.
- SD, Schedule Downtime.
- USD, Unscheduled Downtime.
- OT, Overtime.
- CT, Cycle Time.
- TP, Total Production.
- R, Rejects.

$$PPT = PPT - (SD + USD + OT) \quad \text{[Eq. 3]}$$

The availability column formula respects the theory of the OEE calculations shown in Equation 4. The same is valid for the performance, quality and OEE column – as shown in Equation 5 and Equation 6 respectively.

$$Availability = \frac{OT}{PPT} \quad \text{[Eq. 4]}$$

$$Performance = TP * \frac{CT}{OT} \quad \text{[Eq. 5]}$$

$$Quality = \frac{TP - R}{TP} \quad \text{[Eq. 6]}$$

The values on the "average" row represent the average of all the results obtained on each operation. At the end, the calculator returns the OEE of all the operations performed by the machine. After, the last manual action the operator needs to do to finish the OEE calculations is to input the results of the OEE on the data tabs. As said before there are two tabs for each month of the year. The first one is where the data is stored and the other one is where the data is displayed in charts.

Part of the data tab from January is represented in Figure 21 (the full tab is available in the Appendix B). As seen, all the information is organized by machine, part and then operation, similarly to the calculator organization scheme. The operator must populate the white columns, meanwhile the grey columns will auto populate themselves with the average.

When the tab is filled with data, it is possible to see the OEE and its factors per machine per day and at the end of the average column the machine's OEE of the month. The same is valid for the overall cell's OEE. At the very right side of the tab is a column called OEE where the average of the OEE and its factors are displayed over time and at the end of the column the average of those averages, giving the overall cell's OEE of the month.

For each monthly tab with data there is one following tab with charts, from now on all the tool is automated and the goal was to treat the data and represent it in the best way possible.

In the Figure 22 there is an excerpt from the data tab (the full tab is available in the Appendix C. This tab represents the data on the previous tab visually by using charts. This way it is easy to analyse the gathered data in a detailed level, because is possible to see the OEE and also its factors by machine during the month.

Besides having two charts for each machine as the figure demonstrates, there is another one with the overall cell's OEE. Thereby not only is possible to track the cell's OEE but also its factors in a daily or weekly basis, depending on the team's decision of how to track the OEE.

Machine	2																					
Part No.	PART 4																					
Operation	10			20			30			40			50			60			Average			
Date	A	P	Q	A	P	Q	A	P	Q	A	P	Q	A	P	Q	A	P	Q	A	P	Q	OEE
01/04/2014	94,5%	79,3%	100,0%	93,8%	76,2%	100,0%	94,5%	79,3%	93,8%	95,4%	81,8%	100,0%	95,4%	86,5%	100,0%	94,5%	79,3%	100,0%	94,5%	79,3%	100,0%	75,0%
02/04/2014																						
03/04/2014																						
04/04/2014																						
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25/04/2014																						
26/04/2014																						
27/04/2014																						
28/04/2014																						
29/04/2014																						
30/04/2014																						
																			Monthly Average			
																			A	P	Q	OEE
																			94,5%	79,3%	100,0%	75,0%

CELL			
Average			
A	P	Q	OEE
97,0%	92,2%	100,0%	89,5%
Monthly CELL Average			
A	P	Q	OEE
97,0%	92,2%	100,0%	89,5%

Figure 21 - Excerpt from the data tab of April.

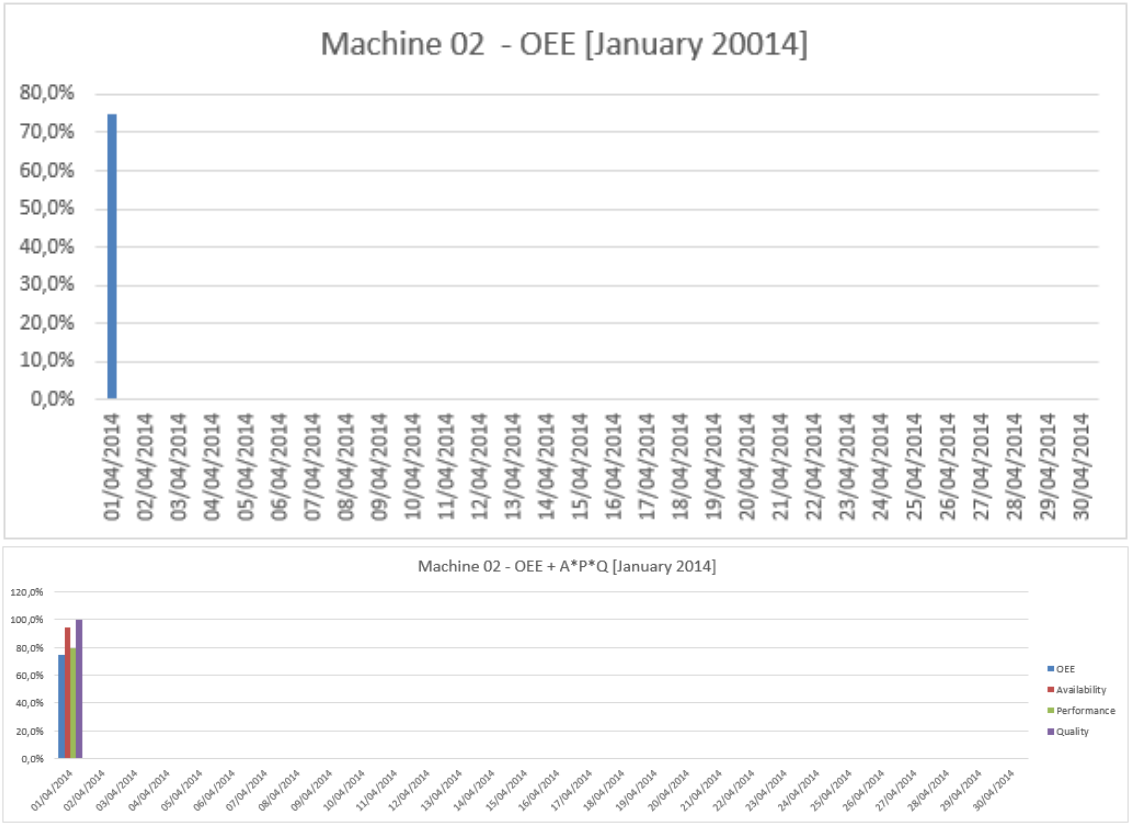


Figure 22 - Excerpt from the chart tab from April.

Showing the visual information about the gathered data in such specific way is important and useful for the team to analyse in a deep manner. However, this tab gives the OEE in a daily basis, so it might be difficult to see the big picture with such amount of data.

That is why the next tab is a summary of the data over time by month – see the Figure 23 (the full tab is available in the Appendix D). As shown, the first part of the summary tab is a table. This table condenses all the information gathered in the previous tabs. At total 288 cells were linked from the monthly data tabs to the table shown in the Figure 23

Figure 23.

Below the table there are charts representing the data visually. Therefore, if an odd variation is noticed, the warning is more appealing if coming from a visual source. Once noticed, the table must be consulted to analyse the variation quantitatively.

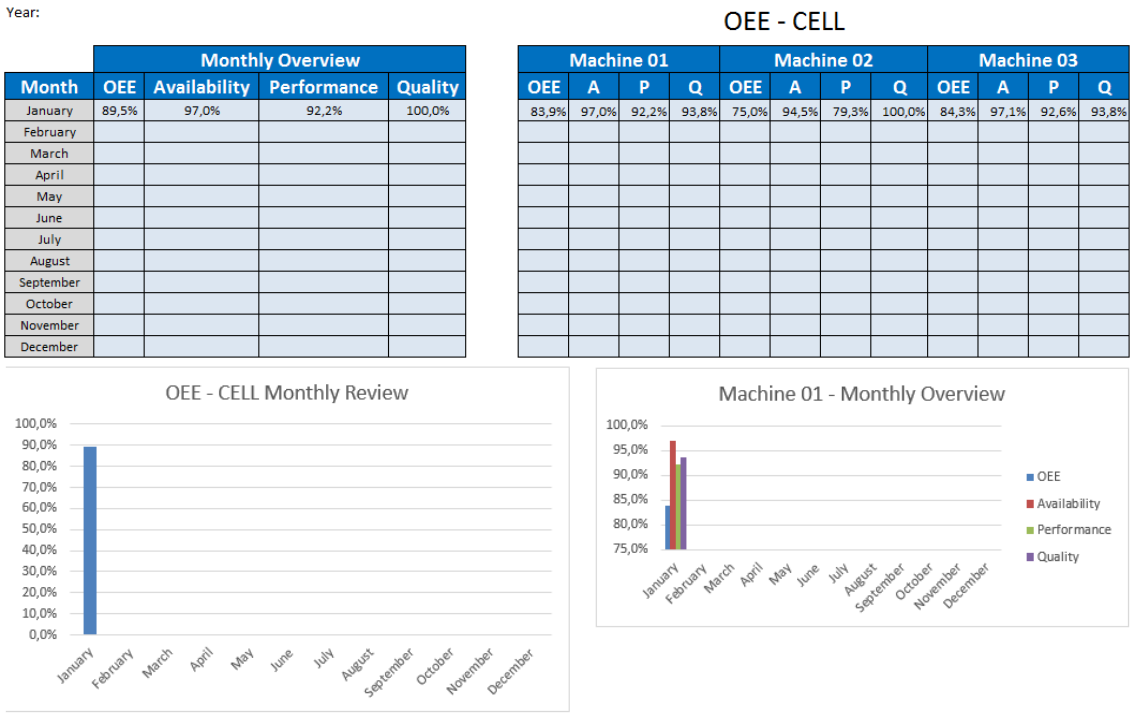


Figure 23 - Excerpt from the OEE summary tab.

The next tab was designed to integrate the visual management boards. It contains the same information as the last table with a different modification. It was added a graph to be manually filled by the responsible to update the visual management boards at the cell.

The period of time between updating charts and printing them every day, might be time consuming and as studied, motion is one of the wastes. Therefore, a manual chart might be the solution. Across the cell are computers that are free to use by the operators, so the operators can use the OEE calculator and update the data on situ. With those results, they have the enough information to populate the OEE graph manually – showed in the Figure 24 (the full tab is available in the Appendix E).

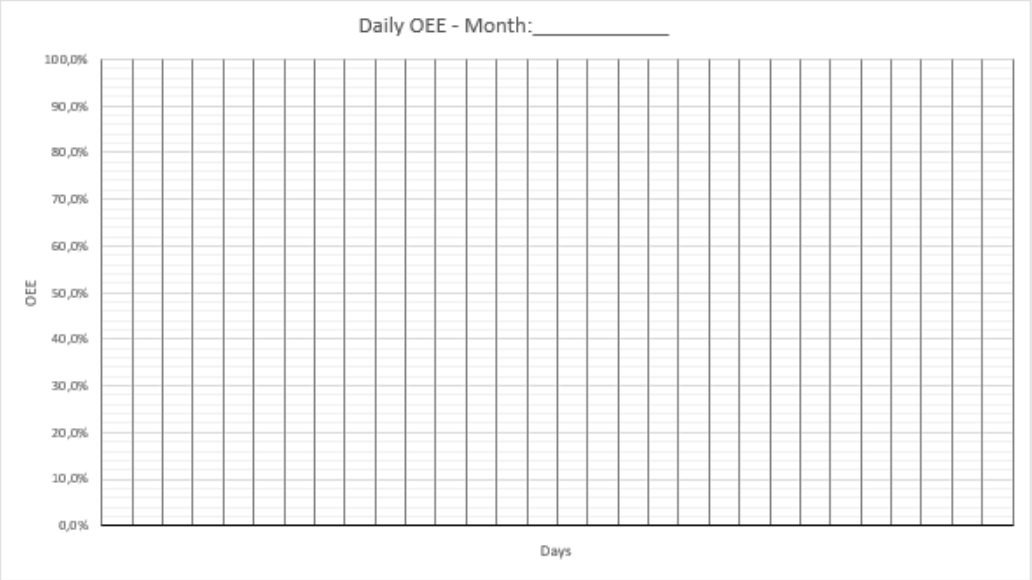


Figure 24 – Daily OEE graph from the Visual Management Board tab.

Lately during the project, it was decided to include the OEE within the visual management board in other format so it could be understood by anyone across the company regardless education.

The last tab for this tool is what can be called the OEE level 1. The idea is that the level 1 is the simplest way of representing the data. Its goal is to inform very quickly if the KPI in question is under controlled, by displaying a red our green warning. The red is for bad, in other words, this sign is used if something is not in line with the established. On the other side, the green sign is for good, in other words, it is used if everything is in line with the established.

This way, without needing to understand the calculations behind the OEE anyone can tell if this indicator is in conformance. As shown in the Figure 25, there are four squares with information. The actual and target spaces inform about the current value of the OEE, again it can be daily or weekly values for example. Either way is the quantitative information in this board. The other two spaces on the bottom are visual information. First, a graph as others presented with evolution of the OEE over time, monthly, but in this case it was added a line with the target. The last space is left for a coloured signed. In the example showed, since the actual value is bigger than the target the coloured sign is green, informing that this KPI is above the target, as wanted to.

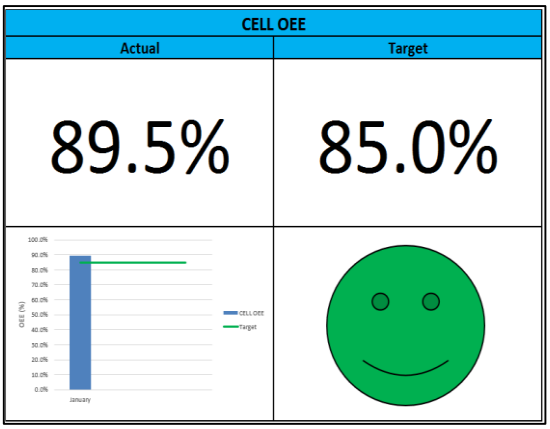


Figure 25 – Level 1 OEE board.

3.3.2. Attendance Tracker Metric

The attendance tracker was design to track the variations of the operators' punctuality. In order to do this a KPI was created, so independently of the shift it is possible to compare the punctuality of operators regardless the shift they are on.

The concept is simple, Equation 7 shows how the relation between the two variables is established. The equation gives back the variation and tells if it is positive or negative. For example, if the operator comes early to begin his shift then the variation will be negative. On the other way, if the operator comes late then the variation is positive, indicative of a bad sign.

$$[AT] = \frac{[(Clock\ in\ or\ out\ planned) - (Actual\ Clock\ in\ or\ out)]}{(Actual\ Clock\ in\ or\ out)} \qquad \text{[Eq. 7]}$$

However, if the same exercise is done for when the operator clocks out, two things can happen. First, the operator cannot clock out before the shift ends because the system will not allow that. But, if the operator clocks out after the end of the shift the variation will be positive.

The log table where the times can be write down is automated so it can calculate and foresee all the possible results. Equation 8 is the formula used on the clock out column and the same equation is represented in a flowchart – see Figure 26.

IF(AND(NSCO=0;OTCO=0);"";IF(AND(OTCO=0;NSCO<EoNS);"EROR";IF(AND(NSCO<>0;OTCO=0);(NSCO-EoNS)/EoNS;IF(AND(NSCO<>0;OTCO<>0);"ERROR";IF((OTCO<=(EoNS+30min));"NORMAL SHIFT";(OTCO-EoOTS)/EoOTS))))) [Eq. 8]

The function used is a sequence of functions type “IF” as used before. To explain how it works, it is easier to follow the flowchart along with the excerpt of the log table where the times must be written - presented in the Figure 27.

The function can be divided into five conditions. The first says that if the content of the cell is 0 then the cell will return a blank space.

If not, then comes the second condition. If the end of the normal shift clock out is earlier than the end of the normal shift and the overtime clock out is equal to zero, then an “ERROR” message is displayed inside the cell. This happens because the system do not allow the operators to clock out before the end of the shift, so it made no sense to allow the operators to do the same in this table.

If the second condition is not satisfied then comes the third condition. If the normal shift clock out is different from zero and the overtime clock out is equal to zero, then the cell gives back the result from the application of the Equation 7. For this cause, the action of filling the blank spaces went properly without inconvenient, and the result is the KPI.

If the third condition is not satisfied then comes the fourth condition. If the normal shift clock out is different from zero and the overtime clock out too, then an “ERROR” message is displayed inside the cell. This is meant to be an error proof action, by displaying an error message the operators are disabled from knowing the clock out deviation. Therefore, the only way to obtain the value is by choosing to fill the normal shift clock out or the overtime clock out cell.

If the fourth condition is not satisfied then comes the fifth condition. If the overtime clock out value is equal to the end of the normal shift plus 30 minutes, then a “NORMAL SHIFT” message is displayed inside the cell. It was decided to give a period time to clock out as being the end of the normal shift. After that the clock out would be consider as overtime. Therefore, the operator must re input the same data but on the normal shift clock out cell.

If the fifth condition is not satisfied then, the value for the clock out KPI must be displayed on the cell accordingly to the Equation 7.

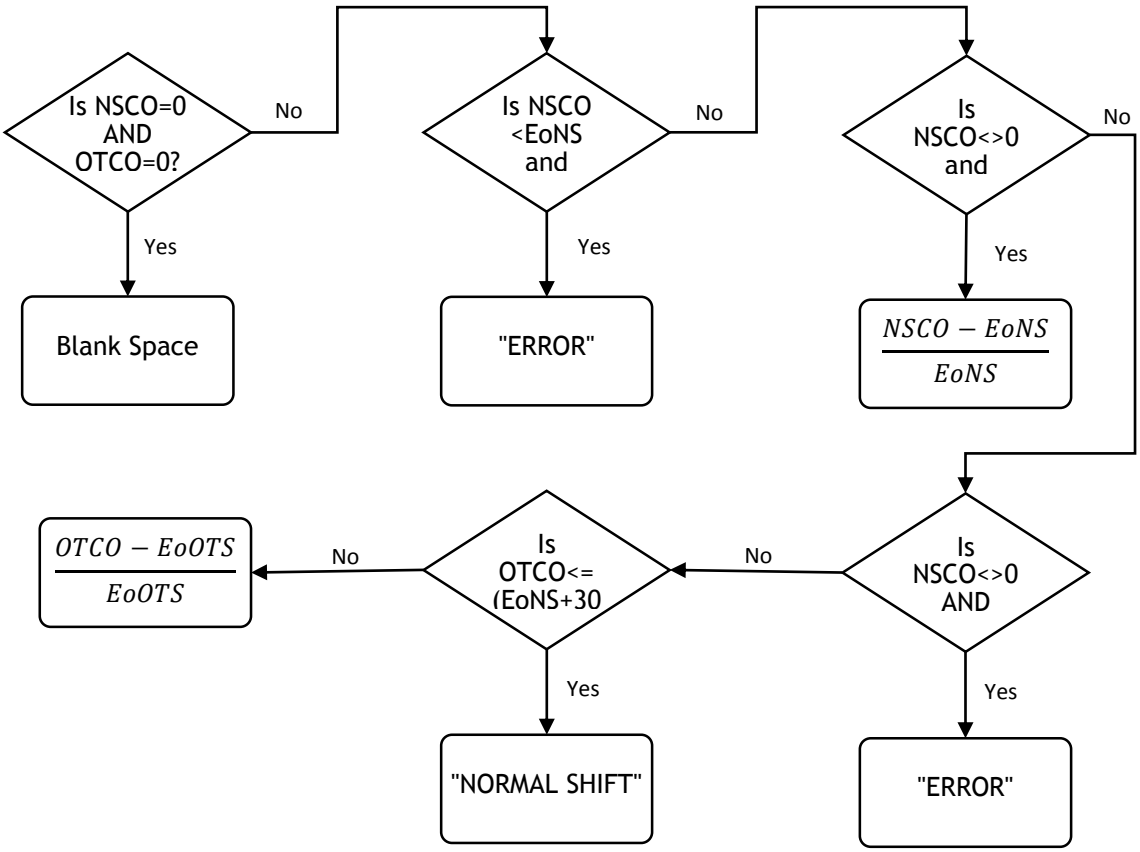


Figure 26 – Flowchart representation of the Equation 8.

Working Days	Day Shift				
	Average				
	08:32:15		16:32:16		
	Clock In	[Clock In]	Normal Shift - Clock Out	OT - Clock Out	[Clock Out]
06/01/2014	08:00:00	0,0%	16:28:00		ERROR
07/01/2014	08:01:30	0,3%	16:30:00		0,0%
08/01/2014	08:03:00	0,6%	16:35:00		0,5%
09/01/2014	08:04:30	0,9%	16:58:00	16:26:00	ERROR
10/01/2014	08:06:00	1,3%		16:30:00	NORMAL SHIFT
11/01/2014					
12/01/2014					
13/01/2014				19:30:00	0,0%
14/01/2014				19:35:00	0,4%
15/01/2014					
16/01/2014					
17/01/2014					

Figure 27 - Attendance Tracker log table.

Alongside with the table where the data from the attendance tracker is input there is another one with the summary of the attendance tracker – shown in the Figure 28. This last one is automated and updated whilst the first one is populated. The purpose of this one is to give a bigger idea of the big picture by watching the evolution of this KPI monthly.

	Day Shift		Day Shift Overtime		Night Shift		Night Shift Overtime		Weekend Shift	
	Clock In	Clock Out	Clock In	Clock Out	Clock In	Clock Out	Clock In	Clock Out	Clock In	Clock Out
January										
February										
March										
April										
May										
June										
July										
August										
September										
October										
November										
December										

	Day and OT Day Shift		Night and OT Night Shift		Weekend Shift	
	Clock In	Clock Out	Clock In	Clock Out	Clock In	Clock Out
January						
February						
March						
April						
May						
June						
July						
August						
September						
October						
November						
December						

Figure 28 - Summary table of the attendance tracker.

The same purpose was aimed when making charts with the data from the attendance tracker summary table. At the end, the board integrated into the visual management board has both the summary table and charts – see Figure 29.

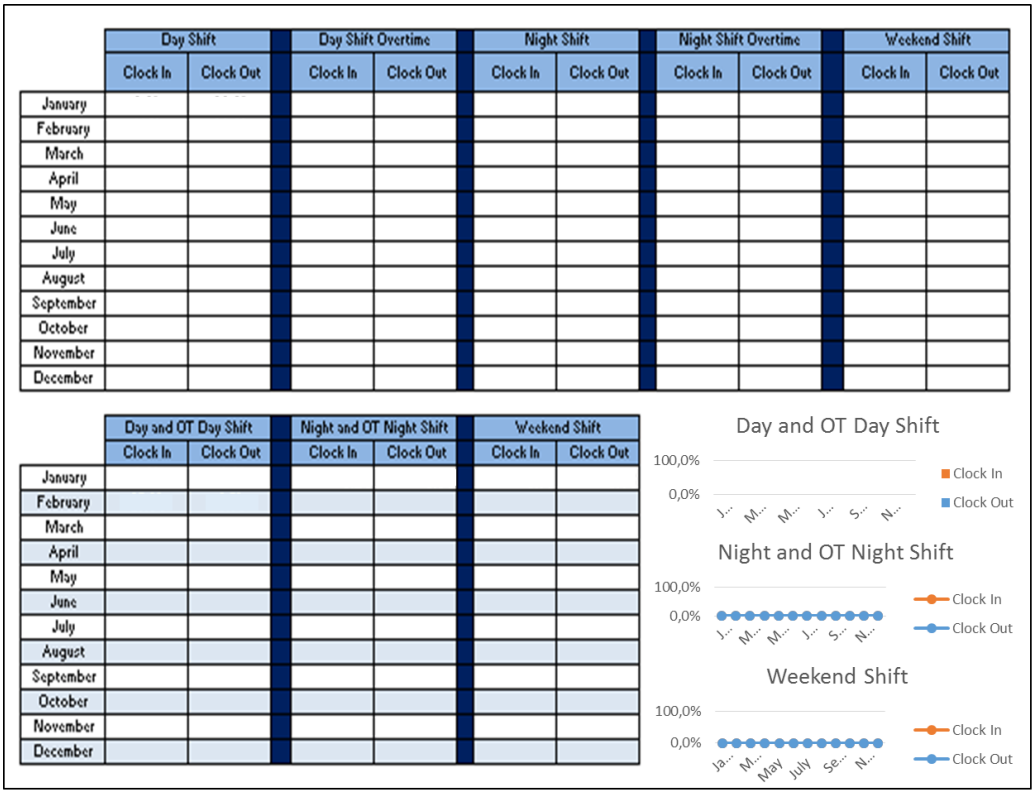


Figure 29 - Attendance tracker board for the visual management board.

3.3.3. Holiday Plans Board

The holiday plans is a board where the responsible to update the boards can mark the holidays and days off of the cell's operators. The board is designed to be edited on paper. The goal was to make a helpful tool for the foreman.

All the information about the operators' holidays is on the system and can be accessed at any time by logging in into a computer. But having a visual tool on the board where the holidays of all the cell's operators are put together on a calendar, might be helpful to help the foreman when planning the production.

In the Figure 30 is the holiday plans board. There, is possible to see that the mechanics behind the board is quite simple. Every operator has a colour. With that colour the responsible should mark on the calendar the holidays of each operator. Also, the days when the shopfloor is closed are marked as red. For each month there are 3 lines to avoid possible interceptions of lines in case they are more than 2 operators off at the same time.

This way when consulting the visual management boards is easier to see when the operators are available and how to fit the workload further in the future. The bigger picture given by this board might allow to detect issues like, for example, not having enough manpower due to too many cell's operators being off at the same time. Because of that, it might be necessary to allocate other operators from other sectors outside the cell. Even worst, it might be necessary to train other operators to fill the position while the operator is off.

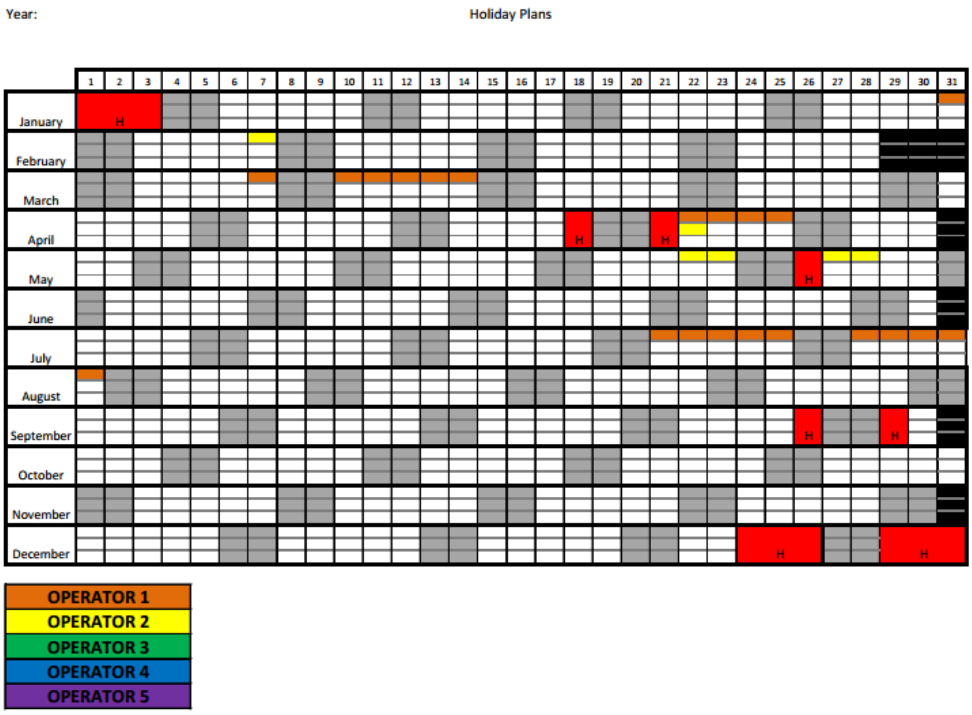


Figure 30 - Holiday plans board.

3.3.4. Right First Time Metric

The right first time is an indicator that tells how good the process is delivering good parts at its first attempt, or without having nonconformities – see the Equation 9. Therefore, when a work order of x parts is issued, then the process in order to achieve 100% must attempt to produce the parts x times. This way, if the number of attempts is bigger than x, then the right first time is less than 100%.

$$RFT = \frac{Actual}{Demand} \qquad \text{[Eq. 9]}$$

The tool developed has four tabs at total. The first one is the data tab, where all the information is input. The second, third and fourth one are the right first time level 1, 2 and 3, respectively. The boards become more general from the level 3 to 1, being the level 1 the main board used on the visual management board to represent the RFT.

In the Figure 31 there is an excerpt of how the data can be found inside the data tab. As shown, for each week of production there is a line for each part. When populating the information it is asked to log the works order, for traceability purposes. The next column is the amount of attempts to produce the part. The other two columns are there to count the nonconformities as scrap or reworked pieces.

Part No.	Week 1				W/C:	
	W/O	Attempts to produce	Scrap	RW	Actual	Actual [%]
PART 1						
PART 2						
PART 3						
PART 4						
PART 5						

Figure 31 - Excerpt from the data tab of the right first time tool.

After filling these four columns, there are enough data to calculate the KPI. Another variable needed in order to proceed to the calculation of the right first time indicator is the actual parts, this means, parts produced right at the first time. In other words it is the amount of attempts minus the scrap and the rework. The indicator is a ratio between the actual parts produced at the first time and the attempts to produce them– the formula used is represented in the Equation 10.

$$RFT = \frac{Actual\ Parts\ Produced}{Attempts\ to\ Produce} \qquad \text{[Eq. 10]}$$

Once the data tab is populated the level 2 tab becomes available to access. The level 2 board is a visual representation of the collected data. As shown in the Figure 32, the charts represent the data in a quantitative way. Also, it is possible to know the amount of the reworks and scrap parts at the bottom of each chart. This way, there is no need to consult the data tab that might be overwhelming due to the amount of data in it.

On the level 2 board there are one chart for each part, and on these charts is possible to compare the parts produced right for the first time across the last 4 weeks. It was added a sixth chart, compiling the 5 right first time parts indicator in one week, preferable the previous one. With this chart is possible to compare the right first time indicator across the five different parts at the same week.

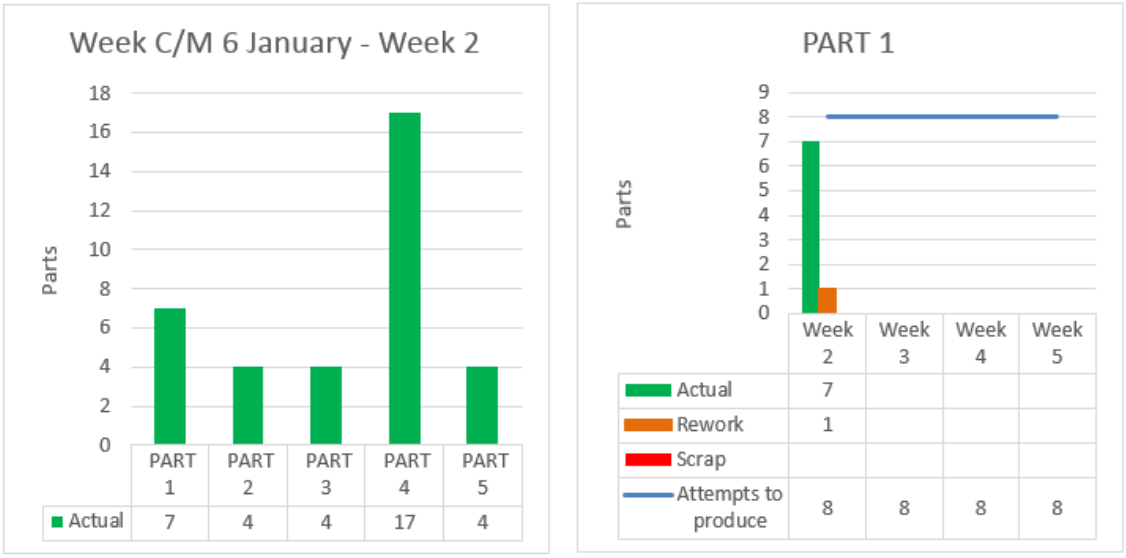


Figure 32 - Excerpt from the level 2 right first time tab.

On the level 1 board there are one chart for each part, and on these charts is possible to compare the indicator across the last 4 weeks. It was added a sixth chart, compiling the 5 parts' indicator in one week, preferable the previous one. With this chart is possible to compare the indicator across the five different parts at the same week. The level 1, 2 and 3 boards are available to consult in the Appendix E.

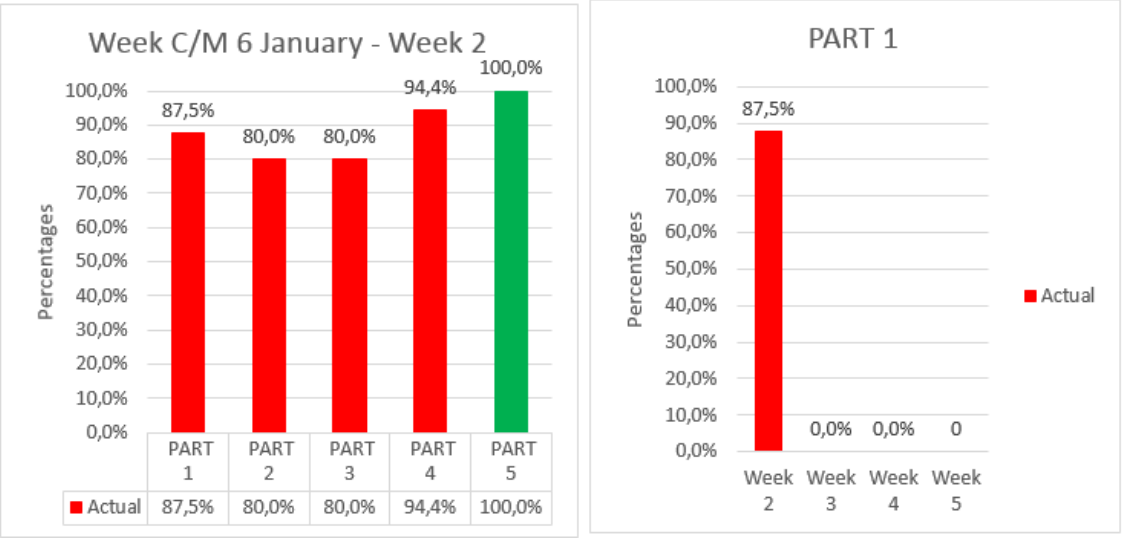


Figure 33 - Excerpt from the level 1 right first time tab.

3.3.5. On Time in Full Metric

The On Time in Full (OTIF) is a KPI representing how well does the process delivers the clients' demand as scheduled, regardless the nonconformities. This way, this tool is formed by three tabs, being the first one the data tab, the second one the level 2 board where the information is presented and the third one the main board level 1 to present in the visual management boards. The KPI's formula is a ratio between the client's demand and the parts delivered – see Equation 11.

$$OTIF = \frac{Delivered}{Demand} \quad \text{[Eq. 11]}$$

The data tab, presented in the Figure 34, is composed by four columns. Three of them are meant to be filled by the responsible, being them:

- Work order, for traceability purposes.
- Demand made by the client.
- The amount of parts delivered in time.
- Delivery / Demand – this column returns the ratio presented on the Equation 11.

The same was repeated for each part.

	PART 1			Delivery / Demand
	W/O	Demand	Delivered	
Week 1				
Week 2	862141	8	8	100%
Week 3				
Week 4				
Week 5				
Week 6				
Week 7				
Week 8				
Week 9				

Figure 34 - Excerpt from On Time in Full data tab.

Once the data is populated into the data tab then the board starts to form. In the Figure 35 there is an excerpt from the On Time in Full level 2 board used on the visual management boards. As shown, there are one overall chart presenting the OTIF of the five parts put together, giving a general idea of how the cell did in the previous week and giving the chance to compare the different parts. On a more detailed way, five charts are presented for each part, showing the KPI across the last four weeks, enabling the user to see the evolution of a certain part's OTIF. The OTIF full level 2 board is available to consult in the Appendix F.

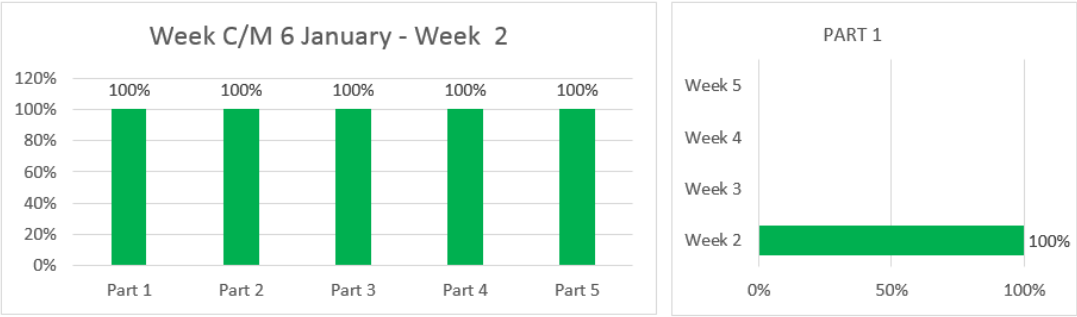


Figure 35 - Excerpt from the On Time in Full level 1 board.

3.3.6. Launch on Time Calculator

The Launch on Time (LoT) is a tool specially designed to help the foreman with the production time. It consists in two tabs being the first one a calculator and the second one a board to mark the launch and the delivering dates of the orders. When a works order is created one of its contents is the estimated delivery date. In order to meet the delivery date, the production planner must prepare and manage the workload, to make sure every order is completed without delaying. At the end, the planner must be able to release a launch date, the date where the manufacturing of the parts ordered begin.

To help in these activities a LoT calculator was created. This calculator gives back what should be the launch date accordingly to the part and delivery date. The calculator works with the following logic. On the background there is a matrix with all of the working days of the year

in one column and another column with numbers starting from 1 in a crescent order. The idea is to assign an individual number to each date. Still on the background, there is one table – see Figure 36 – with the parts produced on the cell listed. On their right there is the time that was established as being the lead time for those parts.

As shown in the Figure 36, there is a list on the first column, this list is linked to the table in the Figure 37. Once the user picks a part, the number of working days for the part to be manufactured, or the lead time, is displayed on the second column. In the third column it is asked to the user to input the delivery date. Once the delivery date is populated then the formula integrated on the fourth column will return the launch date.

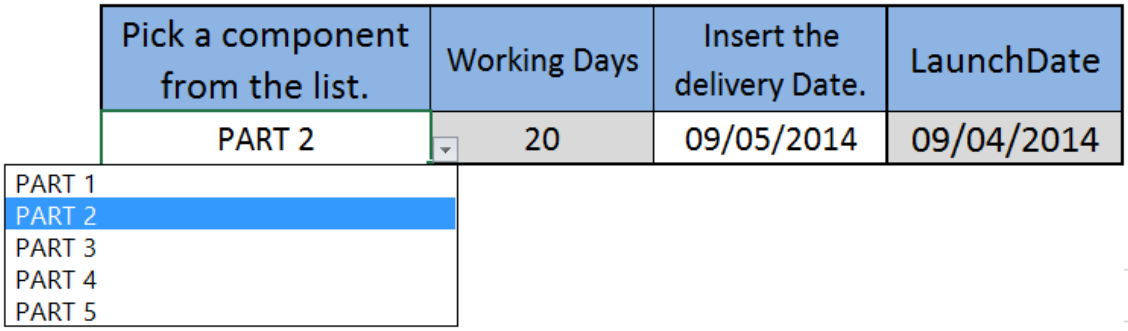


Figure 36 - Launch on Time calculator.

	Weeks	Working Days
PART 1	4	20
PART 2	4	20
PART 3	4	20
PART 4	4	20
PART 5	5	25

Figure 37 - Table with the amount of time needed to produce the parts 1 to 5, in days and in weeks.

The formula in the fourth column is represented in the Equation 12 and illustrated in the flow chart in the Figure 38.

$$LoT = IF(Delivery\ Date = 0; "" ; LOOKUP(MATCH(Delivery\ Date; Matrix;) - Working\ Days; Date\ Column)) \quad \text{[Eq. 12]}$$

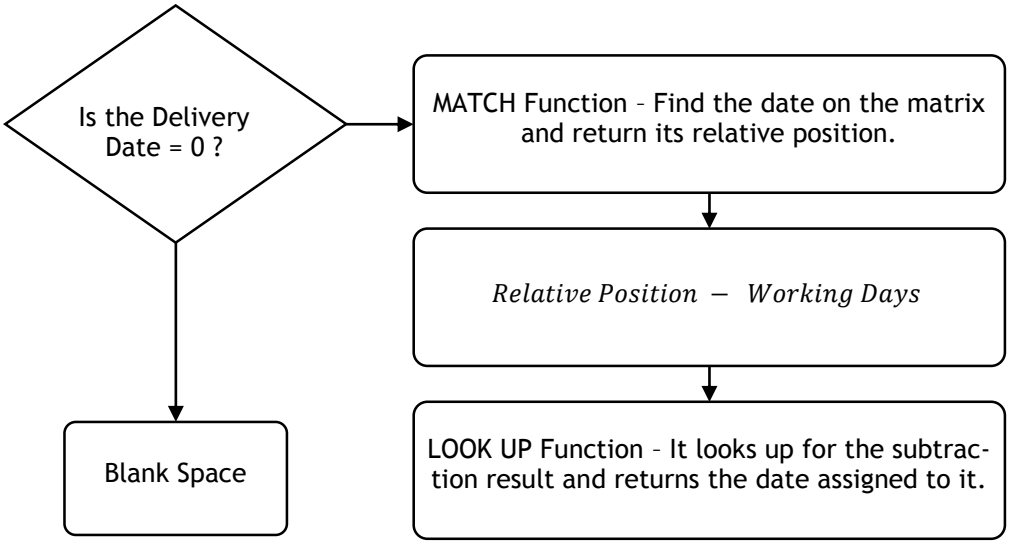


Figure 38 - Flow chart of the Launch on Time formula.

Once the launch date is obtained it is possible to start using the LoT board designed to be a part of the visual management board. The concept is simple, and it is meant to be used on the shopfloor, so not only needs to be simple but very easy to fill and to understand.

In the Figure 39 there is an excerpt from the LoT board. It is a simple calendar with the days the shopfloor is closed and the weekends marked – the full board is available in the Appendix H. A colour was assigned to each part. When a launch date is obtained the responsible should write the work order on the respective cell and then colouring it with the part's colour. The delivering date must be marked the same way as well.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
January	Part 1	H												862369	862369	
	Part 2															
	Part 3															
	Part 4															
	Part 5															

Figure 39 - Excerpt from the Launch on Time board.

If, for some reason, the launch or the delivering date changes then it must be changed on the board like the Figure 39 indicates. In this case, the launch date changed from 13/01 to 14/01.

3.3.7. Scrap & Rework Tracker Board

The Scrap & Rework is quite a simple tool, meant to be purely manual. Its goal is to illustrate the visual management boards, and so, to inform everyone on the shopfloor the impact of having scrap and reworked parts.

In the Figure 40 there is one of the 5 tables inside the Scrap & Rework board, one for each part. Every time a nonconformity appears the board must be filled. The operator must write down:

- The number of the operation
- The NCR, or the Non-Conformance Report number - a report must done every time there is a nonconformity on the shopfloor.
- The date of when the nonconformity happened.
- Quantity.
- S or R. The user must write an “S or an “R” if the nonconformity is a scrap or a reworked part, respectively.
- Cost of S or R. In this space the user must introduce the cost of having such non-conformity. Further in the future the users will have a constant to calculate this field. For example, for a reworked piece they might have to multiply a £/hour constant by the number of hours of work.

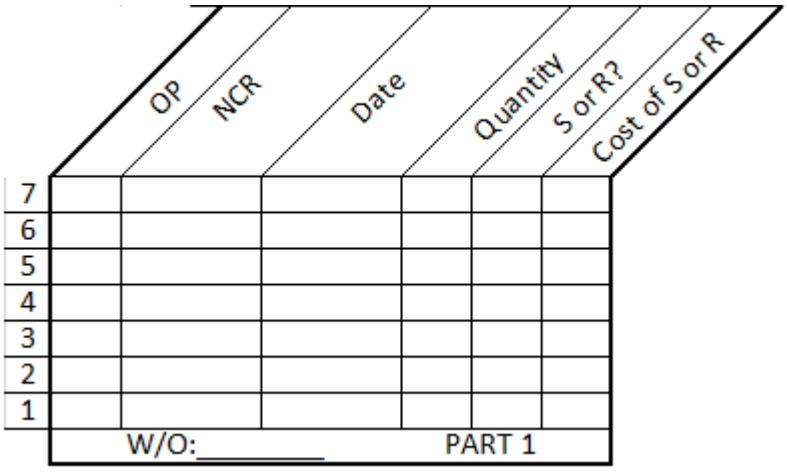


Figure 40 - Excerpt of the Scrap & Rework board.

At the bottom of the board there are four tables as the one in the Figure 41. The intention was to build a table with an overall vision of the nonconformities inside the cell. This way is possible, for example, to identify which parts are having more nonconformities. The scrap & Rework board is available in the Appendix I.

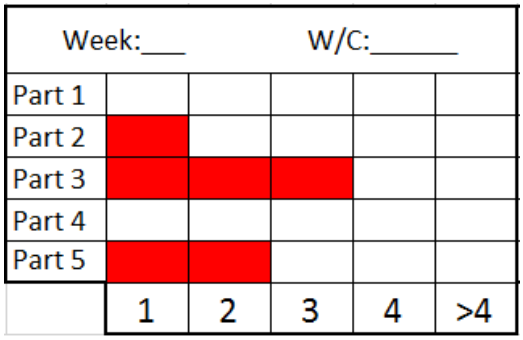


Figure 41 - Bottom summary table of the Scrap & Rework board.

3.3.8. Takt Time, [Setup], [Run] and [Overall] KPIs

This tool is an extensive tool, which calculates the Takt Time for the parts produced within the cell. Also, it measures the deviation from the allowed time given to complete the operations.

This tool can be helpful to identify special variations in the operators' performance. Also, it can help to make adjustments to the allowed time. There are no tools in the company to help controlling the allowed time. When a process is introduced in the company, the project engineers set a standard time (allowed time) for the new operations.

If, during the production the operators have no time to complete the operation within the established time, then the foreman might ask to the project engineer to increase the allowed time.

However, there are no tools to adjust the allowed time in the reverse way. So, this way, the company might have processes with too much allowed time. Because that is normal to happen since processes tend to mature over the time. In other words, they tend to be more efficient due to many factors like the operators mastering the process due to the routine, changes in the tapes turning the programs smaller, faster changeovers, etc.

The tabs created to the Takt Time tool are:

- Concepts
- Data tabs for each month of the year.
- Overall data level 1.
- Overall data level 2.

- Overall data level 3.

- Data Analysis for each part.

The first tab is dedicated to some concepts, to inform the user if for some reasons they are not familiarized or have forgotten some theoretical concepts. They are:

- A simple explanation of the formula used for the KPI that measures the deviation from the allowed time for the set up and running times – see Equation 13.

$$\left[Set\ UP\right] and\ [Run]\ = \left(Taken\ Time\ - Allowed\ Time\right) * 100(Allowed\ Time)^{-1} \quad \text{[Eq. 13]}$$

- Cycle time definition.

- Takt time definition.

The second tab is data tab. Similarly to the OEE tool there are one data tab for each month of the year. Inside each tab there are a table where the user should populate the data in order to calculate the Takt time and the other KPIs.

An example of the tables designed is in the Figure 42. In this table is possible to see that in order to calculate all the KPIs in this tool five fields are requested to be filled:

- Work order, for traceability purposes.

- Week commencing, for traceability purposes.

- Quantity.

- Taken time for the set up and for the running.

The top of the table has two cells to be filled with the cycle time, these cells are locked up and they can only be edited by someone with access to the password.

*TIME IN MINUTES

OP10	[Set up]	-31,3%
(Takt Time LIMIT)	[Run]	-8,3%
35	Takt Time	31
OP20	[Set up]	-18,7%
(Takt Time LIMIT)	[Run]	-2,0%
28	Takt Time	27
OP30	[Set up]	17,5%
(Takt Time LIMIT)	[Run]	14,3%
36	Takt Time	42
OP40	[Set up]	-17,6%
(Takt Time LIMIT)	[Run]	-7,3%
113	Takt Time	104
OP50	[Set up]	-15,3%
(Takt Time LIMIT)	[Run]	1,6%
98	Takt Time	98
OP60	[Set up]	-7,9%
(Takt Time LIMIT)	[Run]	-15,0%
42	Takt Time	36

Monthly Overall			
[Set Up]	[Run]	[Overall]	Takt Time
-15,3%	-3,1%	-4,4%	337

			OP 10					
			Cycle Times [min]		SET UP	120	RUN	30
			SETUP			RUN		
W/O	W/C	Quantity	Allowed	Taken	[Set up]	Allowed	Taken	[Run]
863962	20/jan	18	120	83	-31%	510	510	0%
863973	27/jan	18	120	82	-32%	510	425	-17%
TOTAL		36		165			935	

Figure 42 - Excerpt from the data table of the Takt time tool.

In order to calculate the [Set up] and the [Run] KIPs the Equation 13 was used. The same formula was used to calculate the [Set up] and the [Run] KPIs for the operation. It was a choice not to use the function average, but instead to use the sum of the times and use the Equation 13. Using the function "AVERAGE" would be adding an error to the KPI obtained, unless it was a weighted average instead.

The Takt time was calculated using the ratio presented on the Equation 14. The Takt time was calculated using both the allowed time, to set up a limit Takt time, and the taken time. This way is possible to analyse the actual Takt time against the limit Takt time calculated using the taken time.

$$Takt\ Time = \frac{Allowed\ Time\ or\ Taken\ Time}{Quantity} \qquad \text{[Eq. 14]}$$

The following tab represented on the Figure 43 is an excerpt from the level 3 data tab. On this page all the [Set up], [Run] and [Overall] KPIs and Takt times are condensed in the same table. With this table is possible to build the charts presented in the Figure 44. There are six different charts, one for each part and a sixth one for the overall.

	PART 4			
	TAKT Time	SET UP	RUN	[Overall]
January	337	-15%	-3%	-4%
February	339	-4%	-4%	-4%
March	334	-1%	-6%	-5%

Figure 43 - Excerpt of the table from the level 2 data tab.

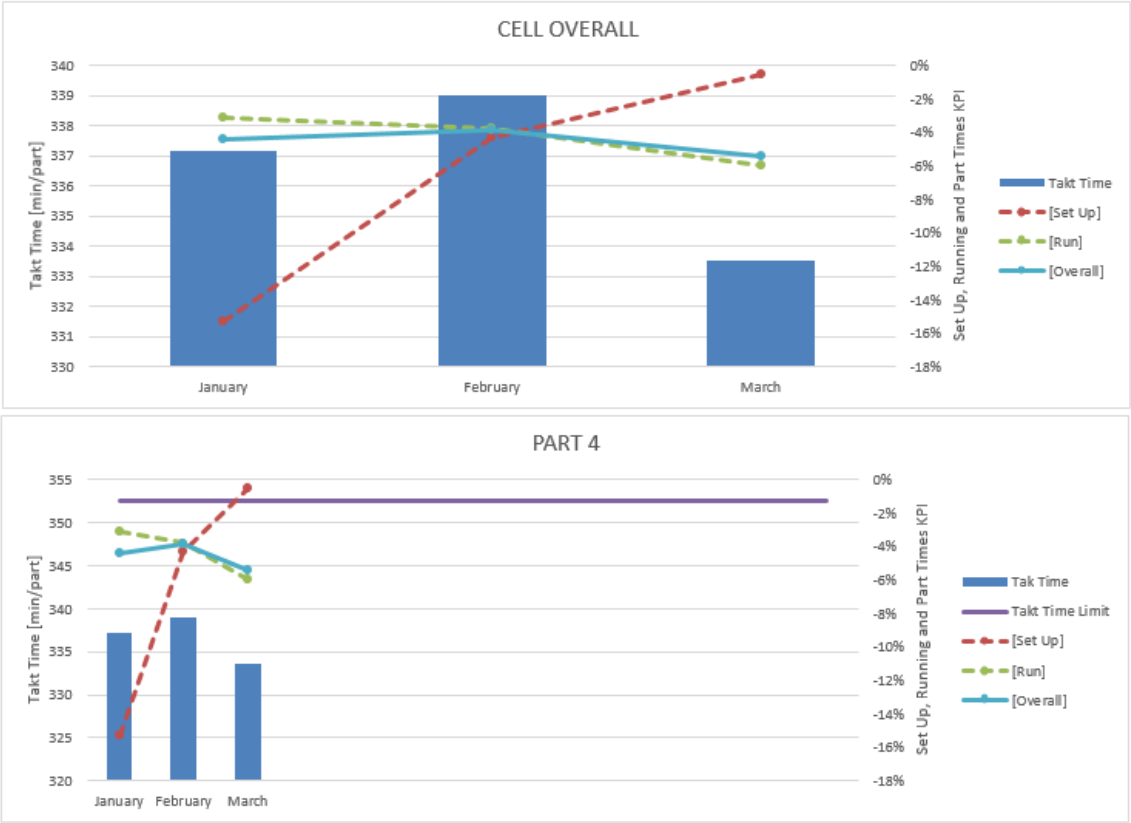


Figure 44 - Excerpt of the charts from the level 2 data tab.

To present the results on the visual management boards, a board was made just containing the charts – available to consult in the Appendix I. This board is a level 2, a level 1 board less detailed – presented on the Figure 45 – only has the actual [Overall] KPI and its target, along with a chart of the [Overall] plus a sign.

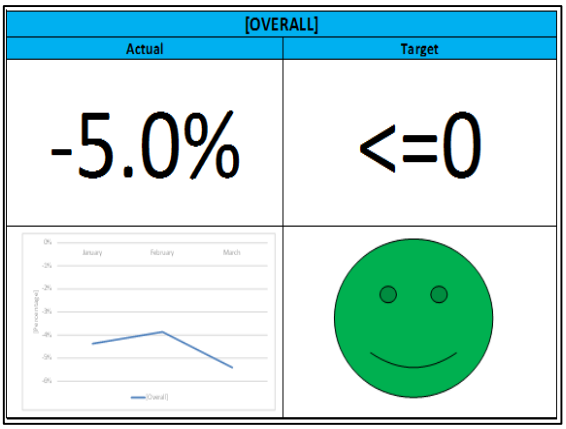


Figure 45 - Level 1 board of the [Overall] KPI.

4.Conclusions and future steps

The main goal of this project was to set up templates for the Standard Operation Procedure and for the Visual Management Board of a manufacturing cell. This way, a standard for the Visual Management Board and also the Standard Operation Procedure was achieved to set across the company and future cells.

The Standard Operations Procedure was a tool reviewed by the cell's senior team. The feedback was overwhelming. With their feedback it was possible to improve the document. For instance, the quality manager told that were some instructions that should be integrated in the SOP. For example it was suggested to integrate how to use the cranes used to lift the heavy parts into the "Manufacturing a Part 1 Cone".

In order to develop the Visual Management boards, several tools were explored, reworked and designed to fit the purposes of Castle Precision.

The OEE, Attendance Tracker, Holiday Plans, Right First Time, On Time in Full, Launch on Time, Scrap & Rework and the Takt Time, [Setup], [Run] and [Overall] tools were formatted and developed using the functionalities of the Microsoft Excel. Thus, this software has proven to be an excellent tool to develop this type of indicators and also to storage data. Due to the short period of time in relation to the amount of tools planned to do, it was not possible to explore the functionalities of the application of Visual Basic in Excel files as wanted to.

The tools developed for the Visual Management Boards were well received near the tutor at the company and also by the Operations Manager. With special attention for the OEE, Launch on Time Calculator and the Takt Time, [Setup], [Run] and [Overall] sheet.

The OEE is not currently implemented by the company and the template developed has given prove of meeting the needs of the company. In the future to improve the OEE calculations it might be beneficial to give to each machine a weight in the average, this way each machine has a certain weight in the overall OEE according to its production.

The same works for the Launch On time, further in other cells, the list of the parts is easily editable. So, it is a helpful tool to calculate the launch date of several parts.

The Takt Time, [Setup], [Run] and [Overall] sheet has proven to be a helpful tool to help to optimize the flow on the shopfloor. It has the power of analyzing the deviation from the allowed times to complete operations.

Castle Precision, as an aerospace manufacturer, has proven to be a company well organized. Their value is on their advanced project engineering skills in developing their products in the most effective way and in their skilled operators. Building manufacturing cells and working on the efficient side of their production, while taking into account the concepts associated with Lean Manufacturing, will lead them to be a more competitive company in the international market.

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Appendix A

Castle
Precision Engineering

PRODUCTION

Manufacturing a Part 1
Cone

Document Number:	CPEPROD0001	Initial Release Date:	28/02/2014
Document Version:	01.A	Last Revised Date:	28/02/2014

SOP Details

Purpose: To ensure a standardized approach is adopted whilst manufacturing a Part 1 cone on Machine-02.

Scope: Manufacturing and in-process inspection of Part 1 cone on Machine 02.

Responsibility: The Cell Leader is responsible for co-ordinating the activities of this procedure.

Definitions: Defines abbreviations and acronyms used in this SOP.

Reference Documents: Part 1 Drawing, Castle Stage Drawings.

Revision History

Page No.	Issue	Revision	Date	Description of Changes
All	1	A	19/02/2014	First Issue

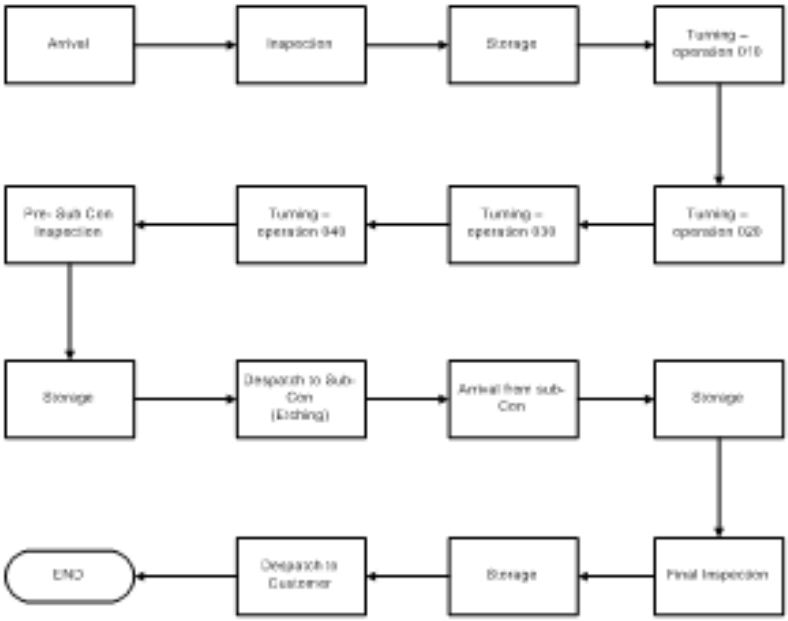
Note: Major changes to the SOP are indicated through 'issue level' changes and minor changes through 'revision level' changes

Minor Change: Doesn't affect the working procedure or process

Major Change: Affects the working procedure or process

Department	Author	Checked By	Approved By	Effective Date
Production				
Visual Inspection				

Flow Map


Arrival
Inspection
Storage
Turning – operation 010
Turning – operation 020
Turning – operation 030
Turning – operation 040
Pre- Sub Con Inspection
Storage
Despatch to Sub-Con (Etching)
Arrival from sub-Con
Storage
Final Inspection
Storage
Despatch to Customer
END

Contents

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OP 20 Production and Visual Inspection Instructions 14
OP 30 Production and Visual Inspection Instructions 21
Appendix A – OP 10 Tooling 29
Appendix B – OP 20 Tooling 32
Appendix C – OP 30 Tooling 35

OP 10 Production and Visual Inspection Instructions

1. Check the route card against the machine control and verify the tape number is the same.
2. Remove fixtures and tools from previous OP.
3. Clean down fixture & clean the screw holes from the previous fixtures with the help of a compressed air gun.
4. Put in grub screws to protect the screw holes of the previous OP fixture.
5. Remove grub screws from OP 10 clamp's positions to ensure correct location of OP10 fixture and the component before the start of the cycle.
6. Remove the forging from the trolley and place it on the workbench and check the serial number to ensure the paper-work is correct (part marking and ticket match).
7. Clean the forging to remove any soil or FOD that could compromise the quality of the component and inspect forging for damage.
8. Place the forging on the main fixture & check with feeler gauge to ensure component is located correctly on the fixture.
9. Place OP10 clamps in their respective positions and tighten them to 40Nm to ensure the component is secured.
10. Load the OP10 tools into the turret and check whether the inserts are changed to fresh edges as per the tooling sheet.
11. Ask an experienced operator to verify whether the tools loaded onto the turret are correct as per the tooling sheet (OP 10) and the Z0 position before the start of the cycle
12. Check G54 & start machining
13. Component is now ready to commence machining.
14. After OP/cycle is complete, clean down the fixture and the component.
15. Check if the 2nd fixture fits & using outside micrometer OM211 measure Ø353.88mm ±0.05mm diameter at 2 positions, 0° and 90°.
16. Unload the component & place it on the workbench (on top of the yellow square) and do the manual checks.
17. Place slip on top face of component. Zero digital depth vernier on top face of part. Using vernier measure 60.00mm ±0.25mm length from slip to flange face of forging.
18. Using GO/NO GO gauge M181 measure 6.74mm ±0.25mm chamfer length. Holding gauge square on top face one side should be above where chamfer and Ø253.88 diameter interseot and the opposite side should be below.
19. Using hand held vibro-etcher; etch 'part number' followed by 'SER' followed by 'unique serial number' (refer to material ticket) on Z0 face.
20. Ensure ticket is ticked up and mark operation as complete on ticket. For the setup check: 1st too.
21. Place the component on the trolley.

Tool No.	T0519 Station Number, Off set number	
Tool Description	ABC1234*	
Insert Description	CNMG 190612*	
Tool Colour Code	Purple	

Appendix B

Figure 46 – Data tab of January from the OEE file.

Machine	1										2													
Part No.	PART 1			PART 5			Average				PART 4													
Operation	10			10							10			20			30			40			50	
Date	A	P	Q	A	P	Q	A	P	Q	OEE	A	P	Q	A	P	Q	A	P	Q	A	P	Q	A	P
01/04/2014	97,6%	91,1%	87,5%	96,5%	93,3%	100,0%	97,0%	92,2%	93,8%	83,9%	94,5%	79,3%	100,0%	93,8%	76,2%	100,0%	94,5%	79,3%	93,8%	95,1%	81,8%	100,0%	96,4%	86,5%
02/04/2014																								
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27/04/2014																								
28/04/2014																								
29/04/2014																								
30/04/2014																								

Monthly Average			
A	P	Q	OEE
97,0%	92,2%	93,8%	83,9%

Figure 47 – Data tab of January from the OEE file. (Continuation)

								3															4
				Average				PART 1			PART 5			Average				PART 1			PART 5		
	60							30			30							20			20		
Q	A	P	Q	A	P	Q	OEE	A	P	Q	A	P	Q	A	P	Q	OEE	A	P	Q	A	P	Q
100,0%	94,5%	79,3%	100,0%	94,5%	79,3%	100,0%	75,0%	98,0%	92,8%	87,5%	96,1%	92,5%	100,0%	97,1%	92,6%	93,8%	84,3%	98,3%	93,9%	100,0%	98,3%	99,3%	100,0%

Monthly Average			
A	P	Q	OEE
94,5%	79,3%	100,0%	75,0%

Monthly Average			
A	P	Q	OEE
97,1%	92,6%	93,8%	84,3%

Figure 48 – Data tab of January from the OEE file. (Continuation)

4				5																				
Average				PART 2									PART 3											
				10			20			30			10			20			30			40			
A	P	Q	OEE	A	P	Q	A	P	Q	A	P	Q	A	P	Q	A	P	Q	A	P	Q	A	P	Q	A
98,3%	96,6%	100,0%	95,0%	95,5%	91,2%	80,0%	96,5%	93,3%	100,0%	95,2%	90,6%	100,0%	92,6%	85,2%	100,0%	92,6%	85,2%	100,0%	96,3%	92,9%	80,0%	92,0%	83,8%	100,0%	95,2%
Monthly Average																									
A	P	Q	OEE																						A
98,3%	96,6%	100,0%	95,0%																						95,2%

Figure 49 – Data tab of January from the OEE file. (Continuation)

				CELL			
Average				Average			
P	Q	OEE		A	P	Q	OEE
90,6%	100,0%	86,2%		97,0%	92,2%	100,0%	89,5%
Monthly Average				Monthly CELL Average			
P	Q	OEE		A	P	Q	OEE
90,6%	100,0%	86,2%		97,0%	92,2%	100,0%	89,5%

Appendix C



Figure 50 - Charts tab of January from the OEE file.

Appendix D

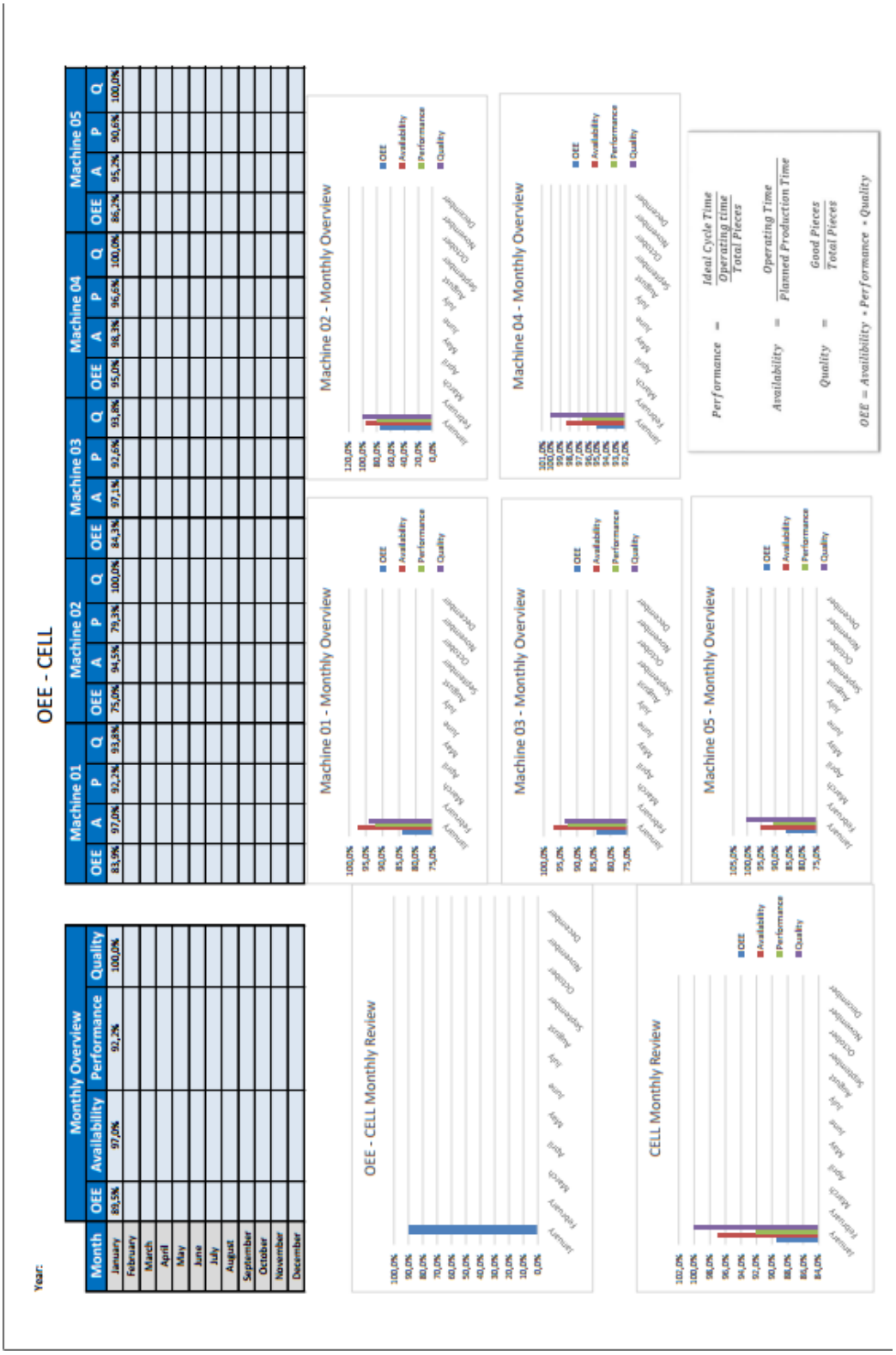


Figure 51 – OEE summary board.

Appendix E

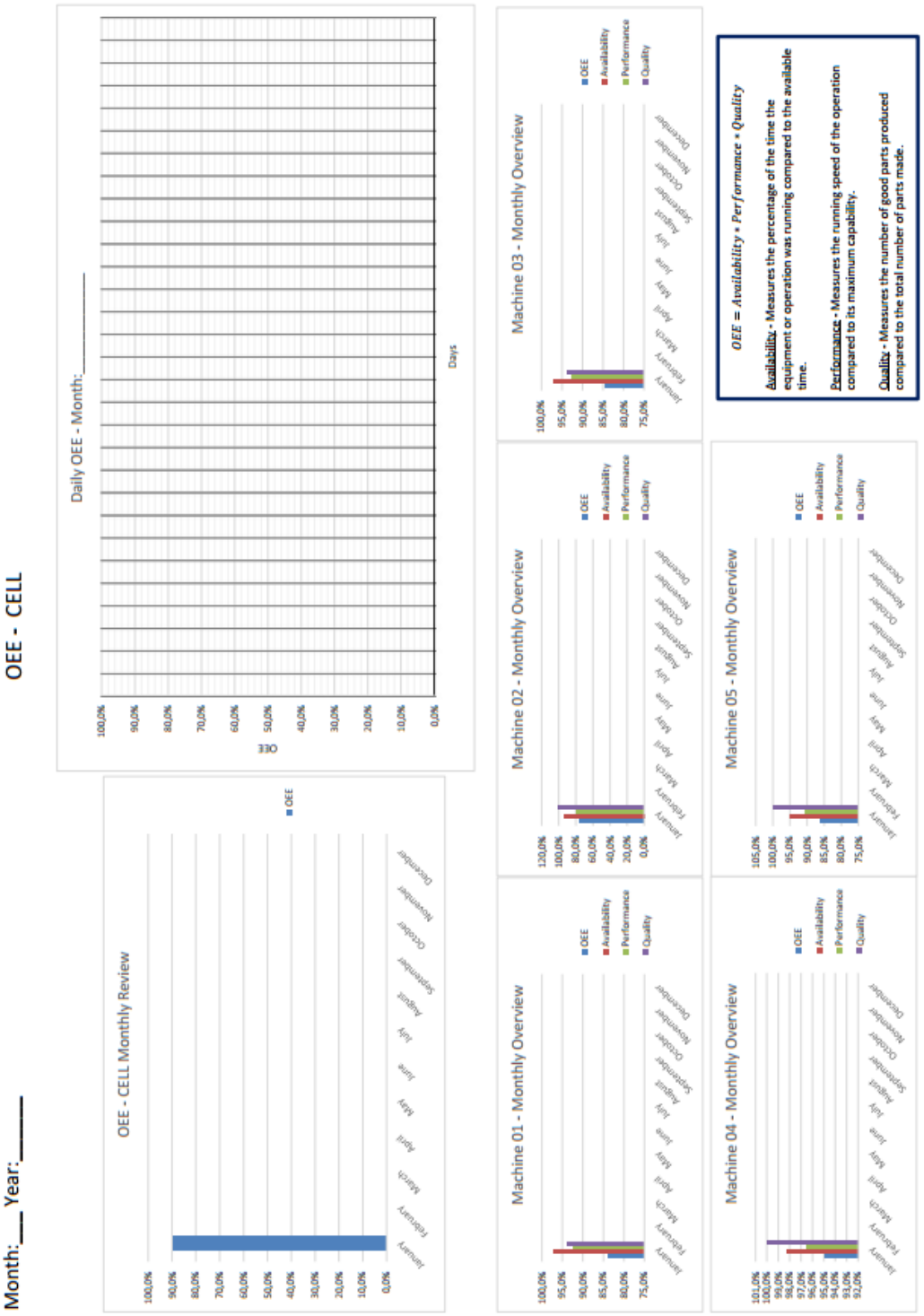


Figure 52 – OEE board with the manual graph.

Appendix F



Figure 53 – Right First Time board level 1.

Figure 54 - Right First Time board level 2.



Appendix G



Figure 55 - On Time In Full level 1 board.

Appendix H

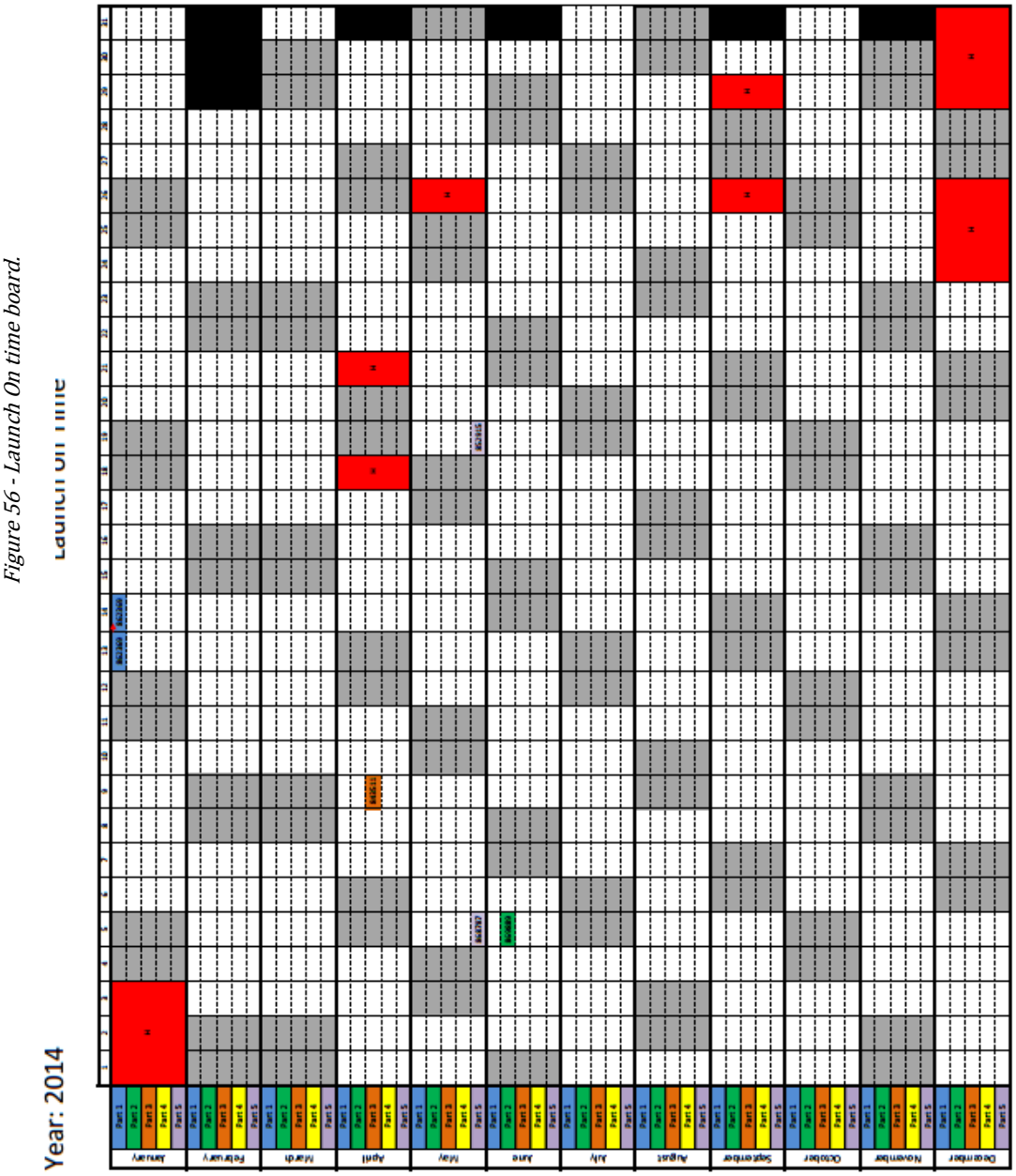


Figure 56 - Launch On time board.

Appendix I

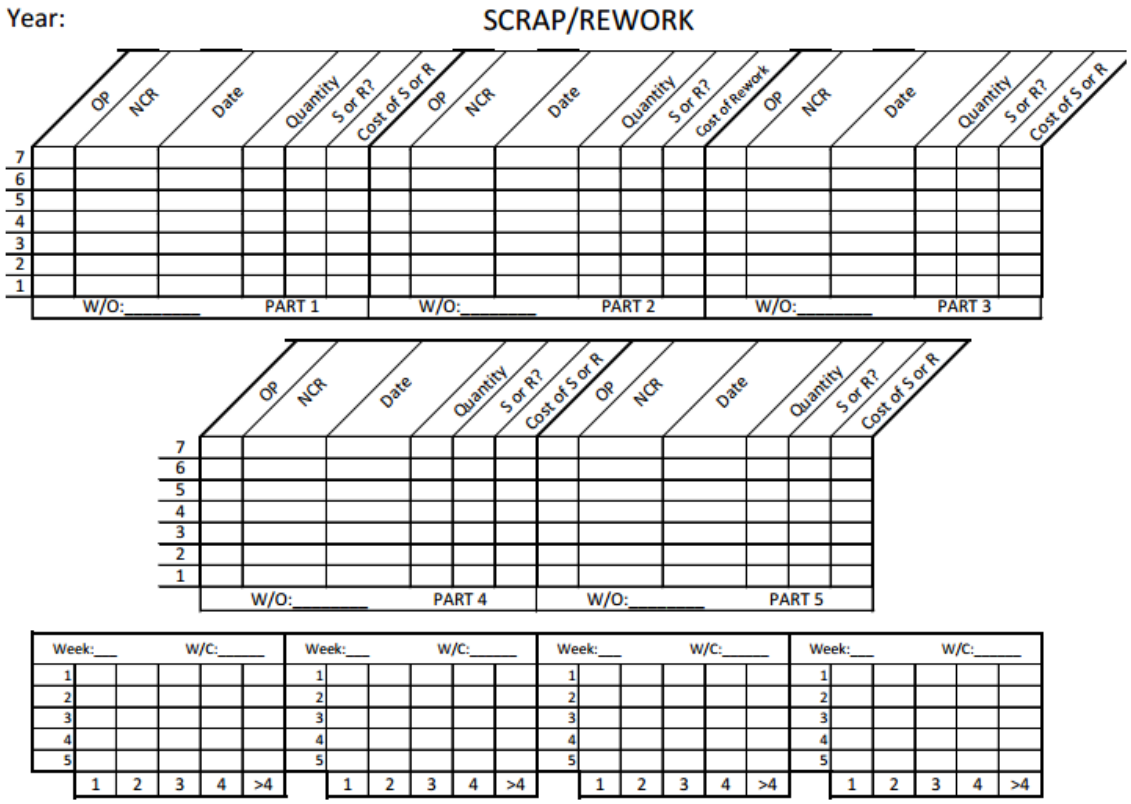


Figure 57 - Scrap & Rework board.