Definition of Autonomous Teams in plastic injection industry

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Master thesis

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“There is no comfort in the growth zone, but there is no growth in the comfort zone”
Joakim Kembro, Professor at the University of Lund

Definição de Equipas Autónomas numa indústria de injeção plástica

Resumo

A *Eugster/Frismag Portugal*, uma empresa fabricante de eletrodomésticos, apresentava variados problemas no seu departamento de injeção plástica. Havia profunda falta de comunicação e alinhamento entre as várias equipas, o tempo médio de mudança de molde era excessivo e a ausência de equipas de suporte em alguns turnos levava a constantes avarias e a uma fraca flexibilidade de produção. Além disso, o bordo de linha e layout desadequados deterioravam a produtividade dos operadores.

Foi criada uma equipa piloto baseada no conceito de equipa autónoma. Esta equipa quebra o paradigma de equipas funcionais ao concentrar na mesma equipa as tarefas que permitem a sua autonomia: manutenção de moldes, mudança e afinação de moldes, controlo de qualidade e embalamento de peças. Ao mesmo tempo, diminui o raio de ação do líder de equipa que fica encarregue de uma equipa mais pequena, conseguindo assim melhorar a sua supervisão e apoio.

Com esta equipa, foi feito um workshop de SMED com vista a criar standards na mudança de moldes e a torná-los mais rápidos. Conseguiu-se com este workshop diminuir o tempo de mudança de molde em 25%. Além disso, foram criados standards para as tarefas mais fundamentais da equipa piloto, para normalizar o trabalho e reduzir a sua variabilidade.

Transversalmente a todo o departamento, foram criadas reuniões diárias – *Kaizen Diário* – nas equipas naturais e entre as mesmas, para melhorar a comunicação e, diariamente, analisar indicadores, planear o trabalho e solucionar problemas de forma focada e organizada. Foi também criado um *mizusumashi*, responsável por todas as tarefas de logística interna, centralizando num único operador todas as tarefas de transporte de materiais.

Por último, dada a situação de crescimento do departamento, com progressivamente mais máquinas de injeção, uma reorganização do layout foi necessária. Esta reorganização permitiu também concentrar máquinas que produziam peças delicadas num só local. Paralelamente, o bordo de linha foi melhorado e 5s implementados no departamento.

Com o aumento de mudanças de molde por dia, a quantidade por lote de produção diminui, para a equipa piloto, em mais de 30% e flexibilizou-se a produção. Além, o OEE aumentou de 83% para 86%.

Definition of Autonomous Teams in plastic injection industry

Abstract

Eugster/Frismag Portugal, a home-appliances manufacturer, presented several problems at its plastic injection department. There was a profound lack of communication and alignment between and within teams, setups took a long time and the absence of support teams during some shifts led to constant machine stoppages and poor production flexibility. Additionally, the border of line and the layout were not adequate to the team and worsen the operators' productivity.

A pilot team was created, based on the concept of autonomous team. This team breaks the functional teams' paradigm by concentrating in a single team all the tasks that allow its autonomy: mold maintenance, mold changing and fine tuning, quality control and plastic parts packing. At the same time, the span of control of the team leader was reduced, allowing for a closer management, supervision and support of his team.

A SMED workshop was carried with the pilot team, in order to create setup standards and make the mold changing faster. With the workshop, the setup time was reduced by 25%. Besides, standards were also created for all the other fundamental tasks the pilot team must perform, to normalize work and reduce its variability.

Transversally to all the department, regular meetings were created – Daily Kaizen – with the natural teams. This is meant to improve communication and alignment and, at a daily basis, analyze indicators, plan the work and solve problems in a focused, organized manner. It was also created a *mizusumashi*, intending to concentrate all internal logistics tasks in a single operator.

Lastly, given the continuous growth of the department due to the arrival of more injection machines, a layout reorganization was necessary. This reorganization also allowed the concentration of machines that produced a very delicate part at a single location. Parallelly, the border of line was improved and 5s implemented throughout the department.

With the increase of mold changes per day, the pilot team average production batch quantity decreased in over 30%, increasing production flexibility. Moreover, the OEE increased from 83% to 86%.

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Index

Acronyms

DP – Plastic Injection Department

EF – Eugster/Frismag

EFP – Eugster/Frismag Portugal

KI – Kaizen Institute

Mizu – Mizusumashi

MMO – Mold Maintenance Operator

OPL – One-Point Lesson

RMM – Raw Materials Mills Responsible

TL – Team Leader

Index of Figures

Index of Tables

1 Introduction

The paper presented is the result of a project carried out throughout the fifth year of the Integrated Master in Engineering and Industrial Management of the University of Porto. It aims to present the project developed with *Kaizen Institute Consulting Group* at the company *Eugster/Frismag Portugal* (EFP). Although the project reached all departments of EFP, this paper will focus on the project developed at the plastic injection department, which had the main purpose of improving the efficiency of the department. This was meant to be accomplished by reorganizing the natural teams, standardizing their work and establishing a continuous improvement culture.

1.1 Kaizen Institute

The Kaizen Institute Consulting Group (KI) was established in 1985 in Switzerland by Masaaki Imai and it is an international consulting firm present in over sixty countries. In Portugal, KI was born in 1999 and has offices in Porto and Lisbon and over one hundred employees.

Kaizen Institute applies the Kaizen Thinking to help companies achieve "operational excellence through quality improvement in products and services, increase productivity and motivate employees" (Kaizen Institute s.d.).

1.2 Eugster/Frismag AG

Eugster/Frismag (EF) is a Suisse company established in 1978 that manufactures house appliances. EF mainly produces high-end coffee machines, around five million per year, making it one of the top players in the market. Currently, EF owns three plants in Switzerland, one in Portugal and has a joint venture in China.

EF operates solely as an OEM, that is, as an Original Equipment Manufacturer. That means EF does not sell products under its own brand. EF sells its products to brands such as Nestlé or Koenig which then sell the products to retailers and to final customers under their own brand.

EFP employs around nine hundred people. In Portugal, it is produced high-end coffee machines and ironing systems. Figures 1 and 2 present the coffee machine *Jura* and one of the *Laurastar* ironing system models, both produced in Portugal.

EFP has two distinct departments, each with an organization of its own, operating at the same plant: an assembly department and a plastic injection department. The plastic injection department (DP) is a direct supplier of parts for the assembly lines, as over 70% of any coffee machine EF manufactures is made of plastic. At the beginning of the project, there were 128 employees at the DP.

The plastic department is physically (see Appendix B and C) and organizationally separated from the assembly department. As it can be seen in Appendix A, EFP follows a **functional**

structure, where people are grouped according to the tasks they perform and their responsibilities.

Figure 2 *Laurastar* GO

Figure 1 – *Jura* Coffee Machine

1.3 Project Context

This project was integrated into a comprehensive project that involves all departments of EFP. The main goal is to increase overall productivity as the Portuguese plant is increasing its production and does not have the capacity to grow.

As for the DP, the main problems noted at the beginning of the project were the following:

- Unclear work standards. There was a “blame” culture where the different teams blamed each other for the problems that occurred. There was also a faulty balancing of operations, creating great disparities between the workload of operators;
- Lack of responsibility and commitment to the job. The teams were unmotivated and only did what was “strictly necessary” to keep things running. Employees showed a slow working rhythm and deadlines were not met. This problem was accentuated due to a large span of control (the team leader of the injection team is responsible for 17 people);
- The deficit of communication and cooperation between teams and within teams. The functional organizational structure resulted in each team working in its “own island” and there was barely alignment between teams;
- The absence of a support team during the night shift and on weekends, causing lower productivity during these times;
- High setup times. The lack of standard work in changing and tuning molds led to above average setup times and low production flexibility, increasing the need to subcontract plastic materials that DP was not able to supply to the production lines;
- Indicators not tracked. It was not visible the losses due to rejection machine availability. This meant a lack of accountability for low productivity and a major difficulty in tracking down problems with its root cause;
- Inefficient layout and disorganized workplace. Operators did not have the equipment and materials needed at hand and need to walk constantly around the shop floor to get them;
- High coverage stocks. Since setups times were long, each production batch was quite large and covered too many production days.

1.4 Project Objectives

The main objectives of the project were the following:

- Increase the OEE (Overall Equipment Efficiency) from 82% to 90% by reducing losses with rejection and machine stoppages;
- Increase production flexibility, by increasing the number of mold changes from 14 to 33 per day;
- Improve workplace organization, the border of line and establish clear work standards to reduce the number of operators needed;
- Redesign layout to accommodate new machines.

At the beginning of the project, it was common to subcontract plastic components because there was not internal capacity to produce them. It is expected that, when the project is over, with the added flexibility and productivity, the need to turn to subcontracting will be lower.

1.5 Methodology

The first weeks of the project were spent analyzing the situation of the DP. With a process-oriented focus, the team spent most of time close to operators, watching how they work and identifying the major issues and losses in productivity. The indicators available were analyzed to get a sense on what were the major concerns to be addressed.

Analyzing the as-is situation, it was noticed that most problems happened due to an inappropriate organizational structure. Thus, the emphasis of the project was to restructure the functional organizational scheme into one that would enhance communication between and within teams, facilitate leadership and increased the department productivity.

Several principles were established, considered vital to attaining the desired goals:

- The teams should be multidisciplinary and capable of solving autonomously their problems;
- Team Leaders should have a smaller span of control;
- Mold problems must be solved 24/7 to avoid large machines stoppage time;
- More setups must be performed per day.

After presenting to the administration the several options designed, a new structure, presented in Appendix D, was chosen. The functional division was replaced by a machine type division, where each team is responsible for a smaller number of machines, all similar between themselves (small, medium or large machines). It was also proposed a dedicated team for the 4 injection machines that produce the coffee machine's tanks: tanks are delicate and require a clean environment. By reorganizing the layout, it was created a space dedicated for these machines, as well as a team that does the tank pre-assemble right off the machine, making it ready for the assembly on the final product.

To implement this new structure, it was first created a pilot team: the "small-machines team", responsible for the 16 smaller plastic injection machines. This team would then be the model for the other 3 teams to be created once the success of it was proven and the team is working in "smooth sailing".

The pilot team is multidisciplinary and autonomous, as mold changing and fine tuning were internalized in this team by concentrating these tasks in the team leader of the team. Moreover, this allows for molds to be changed 24/7. Also, a new figure was created: the mold maintenance operator, integrated into the pilot team, assures mold problems resolution and preventive maintenance 24/7.

In order to establish this team, it was necessary to train employees in this new way of working. The following steps were taken:

- Training program for team leaders, to coach them in change and fine-tune molds and solve issues related to the machines;
- Training problem for mold maintenance operators, in mold preventive maintenance;
- Definition of clear standard work, with the creation of visual norms. It was necessary to follow closely each employee and progressively train them in the new way of thinking;
- Improve setups by developing with the team a workshop about SMED and training them into standardizing the way molds are changed;
- Reorganization of the workspace around the small machines, to improve work conditions and productivity.

In parallel with the creation of this team, other initiatives were taken:

- Following the Kaizen thinking, team meetings – called Daily Kaizen – were created for each natural team (even for those that will cease to exist with the new organizational scheme). With these short meetings, each team working on the shop floor gets aligned, discussing and solving problems, being able to indicators and plan the work;
- Creation of a *mizusumashi* – a logistic train – to concentrate all internal logistics activities (transport of carton boxes to warehouse, replenishment of materials near operators) and to improve the focus of operators on the tasks that add value;
- Redesign layout to group machines by type (small, medium, large and tanks) to allow each team to be concentrated in a smaller space;

The integration of the tanks' pre-assembly right off the machine will not be addressed in this thesis, as the main focus is to analyze the creation of the "pilot team", its pros and cons and the way the creation of small, autonomous teams can impact a plastic injection industry.

1.6 Thesis Structure

The remainder of this document is as follows. In the next chapter, a literature review is performed, presenting the theoretical perspective of the problem and the state of the art in team definition and Kaizen Thinking. It is also presented the distinctive characteristics that shape a plastic injection facility. In Chapter 3, the problem and the initial situation of the company are thoroughly described. Chapter 4 encompasses the description of the solution found and the step by step of its implementation. In the end of this chapter, the results obtained are presented. Finally, Chapter 5 summarizes the key findings of this thesis, suggests further work and discusses the approach to the problem.

2 Theoretical Analysis

2.1 Plastic Injection Molding

2.1.1 The market

Injection molding is the most used manufacturing process to fabricate plastic parts. According to recent reports published by Grand View Research (Grand View Research 2015) and Allied Market Research (Allied Market Research 2016), in 2014 the molded plastic market size held a value of almost 200 billion USD and had a demand of almost 1 million tons. The top used plastic materials are polypropylene (41%), ABS, HDPE and Polyesterine. As for the molded plastic application segment, the top one is packaging (33%), followed by electronics, automotive, construction and medical.

Even though 3D printing – also known as additive manufacturing – has been gaining attention over the last few years, it is still expected for the plastic injection molding market to grow. According to Grand View Research, the market will grow by 4.5% from 2015 to 2022 and, according to Allied Market Research, it will grow by 4.9% between 2015 and 2020.

3D printing brings flexibility, customization and the ability to create highly complex parts. However, with the current technology, it is only cost effective for small batches (Matthew Franchetti 2017). Research on the subject shows that 3D printing is of great advantage for manufacturing rapid prototypes and single units but, from a mass production perspective, injection molding allows to produce more quantity, in a shorter time and with lower costs.

2.1.2 Injection Molding Process

Injection molding machines are hydraulic, mechanic or electric machines which vary in size and complexity. In a broad sense, an injection machine has two main parts: a clamping unit and an injection unit (see figure 3).

Usually, injection molding machines are rated according to the maximum amount of clamping force they can produce: smaller machines might produce clamping forces of only a few tons while larger ones can have clamping forces of over 1000 tons. The required clamping force depends upon (IcoMold s.d.):

- the material used and its viscosity. The greater the viscosity, the more difficult it is to flow and greater injection pressures are needed;
- The projected area of the part. A greater area means a greater need for clamping force;
- The depth of the part. With more depth, more force is needed.

The injection process is very short, usually, bellow 2 minutes, and it is as follows (Custompart.net s.d.):

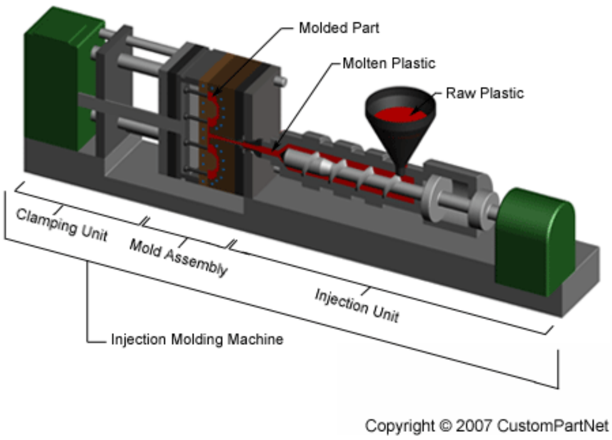

Figure 3 Plastic Injection Machine

- Before the injection takes place, the two halves of the mold are closed by the clamping unit. One-half of the mold is fixed to the machine while the other can slide. The clamping unit must exert enough force to keep the mold closed while the material is injected and cools down;
- When the mold is securely closed, the raw plastic material, in the form of pellets, is melted by the injection unit with heat and pressure. When it is melted, it is rapidly injected into the mold, building a lot of pressure (hence the need for the clamping unit to have enough force to keep the mold together);
- As soon as the molten plastic is in contact with the interior mold surfaces, it begins to cool down. The mold can only be open once the cooling time has passed;
- At the end of the cycle, the mold opens and an ejection mechanism ejects the part.

This is usually not, however, the end of the process. It is normal to have rework done on the parts once they are ejected. When cooled, some plastic solidifies in the channels of the mold – the sprues – and must be separated from the part, either mechanically or manually by an operator. Also, it is normal to find flash along the part produced, which has to be trimmed, usually manually using cutters.

2.1.3 Plastic Injection Facility – Benchmarking EFP Plastic Injection Department

In discrete production assembly lines, each operator performs a specific task at a specific place along a production line, adding something to the final product. As for plastic injection molding, a "traditional" facility like the one analyzed throughout this project has as main character the plastic injection machine. At these facilities, operators are usually responsible for quality control of the plastic parts, for any rework needed (cutting the flash, separating the sprues from the parts) and for packing the plastic parts into carton boxes or alike. Operators usually perform these tasks at several injection machines at once, since the operator cycle time is quite shorter than the machine cycle time. There can also be small assembly lines right in front of the machines, assembling the pieces right away at their final product. Moreover, molds must be changed quite often – depending on the flexibility production needs – which makes mold changing and fine-tuning a key activity.

Then, there are several support activities: machine maintenance, mold maintenance, production planning, raw materials warehousing.

Since this is a very specific kind of production facility, there is not much research done on the subject, but there are industry best practices that one can learn from. Kaizen Institute has done several projects at plastic injection molding facilities, and a comparison between these facilities was made under certain criteria[1]:

- The number of injection machines per tonnage. The tonnage is used to evaluate the complexity of setups since larger machines require bigger, more complex molds that are more difficult to handle and to mount and to fine-tune;
- Types of raw materials used. This criterion is only addressed if a company produces plastic parts in sensitive materials, which tend to increase rejection and lower efficiency;
- Number of operators;
- The number of teams and team leaders. To capture the size of each team, the span of control and how many machines each team is responsible for;

The following indicators were then evaluated for 8 different production sites:

- Average setup times per machine tonnage;
- OEE per machine tonnage, calculated as:

$$OEE = (GP/TTP) * 100 \tag{2.2}$$

Where:

OEE is overall equipment efficiency
GP is the number of good parts produced
TTP is the total amount of parts that could be produced

So, a comparison between EFP and 5 different production sites was performed:

- Company A and B both produce large plastic auto parts ;
- Company C produces toilet plastic parts (cisterns, tubing);
- Company D produces auto parts and electrical safety devices;
- Company E produces audio parts and auto parts (dashboards and displays).

The table 7, in Appendix E, presents the number of injection machines per tonnage in each facility. This gives a sense of the size of the site and variety of part sizes produced. For company D this data was not found.

The table 8, also in Appendix E, presents a comparison between the characteristics of each company. EFP is the company with the highest number of operators. Oddly, it is also the one with the fewest team leaders: Only 1 for 18 people, a span of control of over 3 times any other company, which means the team leader has to divide his time training and supervising more people. Also, during this analysis, it was found that the number of machines per operator and per team is highly variable. While in company C one operator can be responsible for 15 machines, in company E there are machines that have operators dedicated to only 1 machine. This is due to the variation of the operator saturation. Therefore, the number of machines one operator can work simultaneously at any given time depends on:

- The machine cycle time – what is the rate that the machine delivers a new piece;
- The operator cycle time – how much time does the operator spend per piece, doing whatever operations he needs to do (quality control, rework, assembly, packing).

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[1] The benchmark was done based on Kaizen Institute internal data: reports from passed projects and case studies. Hence, the names of the companies cannot be revealed nor there is public data on the matter.

Usually, the operator cycle time is lower than the machine cycle time, allowing him to work on multiple machines. However, in cases where, for example, parts are assembled at the machine, it may be needed to have dedicated operators to machines. This is what happens in company E. Moreover, there are other factors to be accounted for:

- The fragility of the parts produced – it is easily scratched, for example, the operator must use gloves, sometimes has to clean the part and it takes longer to do quality control and to pack;
- The layout – if machines are to spread apart, the operator must walk a lot between machines. This means more wasted time walking around the plant and not adding value;
- Automation – In factory C, there are small devices at the exit of the injection machines that separates pieces from sprues. This eliminates one important task of the operator, reducing the operator cycle time and allowing him to work on more machines.

Finally, in the table 9 in the Appendix E, the setup time and OEE between the 5 facilities is compared. As for setup time, there is immense variability: factory C, A and B have clearly optimized the mold changing process and do it very efficiently. In factory C, for example, operators are able to do several tasks in the setup, helping the mold changer. Also, small improvements in the machines and molds, to allow faster setups, were made. In companies D and E, the material also impacts the changing time: with more frail materials, that require strict quality parameters, fine tuning takes longer. As for EFP, this process is slower and only 3 machines produce parts with delicate materials, which comes to show that there is a huge opportunity for improvement.

As for OEE, companies A and B take the lead. For company C performance losses are not available and for company D this was not measured. Company E has the lowest OEE, mainly because of the lenses that are produced there: again, with stricter quality parameters, such as transparent displays for cars, the rejection is higher, machines stop more often and setups take longer. EFP also shows room for improvement.

2.2 Organizational Structure

There is not one ideal organizational structure, as it depends on the organization, the culture and the goals ambitioned. Whereas the right organizational design contributes greatly to the effectiveness of the organization, a poor design will lead to poor performance and unmotivated employees. To understand the pros and cons of the different components of an organizational structure and how to relate them with EFP, it is necessary to review some fundamental concepts.

2.2.1 Organizational Design

Organizational design is defined as "the process by which managers select and manage aspects of structure and culture so that an organization can control the activities necessary to achieve its goals" (Jones 2010). In designing an organizational structure, two problems are addressed: the division of a big task into small tasks and the coordination of these small tasks so they effectively work together towards the bigger goal (Jones 2010).

There are two major design approaches, opposed to each other:

- **Mechanistic structure –** Usually preferred for predictable, stable environments due to its lack of flexibility and formalization. There is a formalized hierarchy, with centralized decision making. The structure is tall with well-defined rules and standardized tasks (Azevedo 2016).

- **Organic structure** – Suits best volatile environments, where flexibility is needed to adapt to ever-changing conditions. Decision making is decentralized and the structure is flatter. There is less specialization, standardization and formalization (Azevedo 2016).

Figure 4 Mechanistic approach (left) and Organic approach (right)

The hierarchization of an organization starts when there is a need for control and coordination. One of the first steps in creating a structured hierarchy is the **differentiation**. This is "the process by which an organization allocates people and resources to organizational tasks" (Jones 2010). There are two types of differentiation (Azevedo 2016):

- **Vertical differentiation** – The way a hierarchy of authority is created, setting the different levels of the organization and the chain of command;
- **Horizontal differentiation** – The way the organization groups tasks into roles and subunits. This kind of differentiation is based on the specialization given to employees and their tasks.

The creation of a hierarchy will need a balance between principles of a mechanistic and organic structure type, leading to the challenges of balancing:

- Differentiation and integration;
- Decision centralization and decentralization;
- Standardization and mutual adjustment.

Furthermore, other questions are raised regarding the right organizational structure for the company at hand:

- What is the correct span of control?
- How formalized does communication need to be?
- How should employees be grouped?

2.2.2 Span of Control

The span of control is defined by the number of employees that are managed by a manager. This has been and still is an issue when designing organizations since there are two opposing forces coming to play:

- The more employees a manager has to managed, the more difficult it will be to lead and control his employees;
- The more managers a company has, the more expensive it will be for the company and the harder it is to keep all aligned and productivy. Also, there is a risk of employees being overloaded with supervision (managers become "micro-managers").

One of the first articles wrote on the subject was published in 1956 in the Harvard Business Review, by Lyndall F. Urwick. (Urwick 1956). Lyndall analyzes group relationships: he argues that when increasing the number of employees a manager handles, not only the direct relationship between employee and manager must be accounted for, but also the relationships between employees. This means there is an exponential complexity added by the addition of each new subordinate (see figure 5).

Even though most of these parallel relations will hardly ever need attention, having 4 subordinates, for example, means having 44 relations to handle, whereas having 5 subordinates brings this number up to 100 – this is a burden that Lyndall thinks cannot be denied. So, Lydall states that "**no superior can supervise directly the work of more than five or six subordinates whose works interlocks**" (Urwick 1956). The cost of having a span of control too large would be a lack of leadership, poor communication and indecisiveness, leading to unmotivated and unproductive employees.

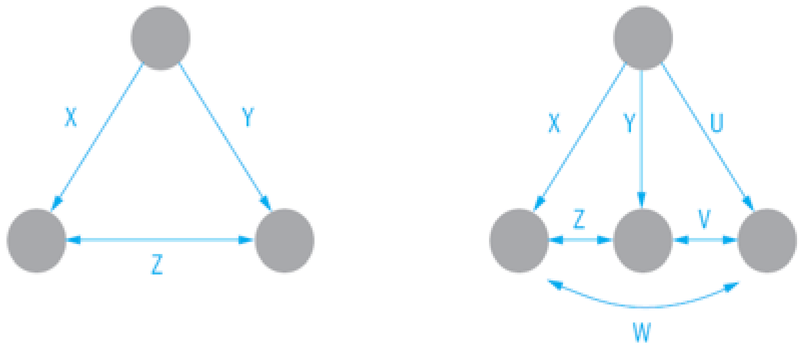

Figure 5 Relationships between a manager and his subordinates

He did, however, recognized that this is not an immutable rule and that "the smaller the responsibility of the group member the larger may be the group" (Urwick 1956), that is, if subordinates have very standard, repeatable and small tasks, the span of control may be larger.

Lydall also exposes, in a surprisingly up-to-date way, why span of control is so many times ignored:

- It is a symbol of status to report directly to higher levels instead to middle managers;
- There is a cost-conscious attitude towards having more managers for the same number of employees;
- It is common to find higher level managers proud of their "efficient executive" and refuse to delegate power.

In 1981, Robert D. Dewar studied several companies to find the impact of 3 different variables – size, routines and number of different specialties – for the definition of the ideal span of control for each hierarchical level of the company (Dewar 1981). Dewar considers that the span of control should be variable along the hierarchy and cannot be generalized since skills and tasks are different for different levels.

The paper shows that the number of different specialties has a significant effect on all levels: at executive level leads to larger spans but spans are lower at middle levels. The interpretation is that specialized employees at lower levels need to be supervised by superiors of "their own kind".

As for size, it only impacts the middle levels, making the span of control larger, but not the first line managers. The degree of routineness showed no effect on the span of control. This study did not, however, considered factors such as tradition, union agreements and other factors that may influence the results.

Another study, also done in 1981, analyzed the impact of the company size and technology (small batch/large batch/continuous process) on 50 Japanese companies. It was found that size had a greater impact on structural differentiation and formalization but technology had the largest impact on the span of control (Robert M. Marsh 1981).

It was found that size increases the span of control since larger companies have more subordinates grouped together, decreasing the need for supervisors. Moreover, as size increases, it is possible to routinize tasks and increase formalization, which also contributes for a larger span of control (Robert M. Marsh 1981). As for technology, the more complex the work and the technology employed, the lower the span of control, since supervision is more time to consume (Robert M. Marsh 1981).

There is not, however, a definite answer on what the right span of control. Early studies showed it should be around 5-8 people, but arguably this may vary depending on cultural factors, industry, the size of the company, technological advances and the skills of the employees.

Span of Control as a Queuing Problem

Supervision can be looked at as a queuing problem, where the supervisor gives a service to all employees under his supervision. In a study by Yuval Cohen, it is presented how to evaluate the right assembly line segmentation. One of the factors to determine this is the span of control since it limits the number of stations or sections one foreman can supervise (Cohen 2013).

Accordingly, when increasing the number of subordinates, a manager must spread his time between more employees, having less time for each. On the other hand, more employees will mean more requests to handle – assuming the number of requests per subordinate will have the same distribution whatever a number of employees there is. Thus, in order to evaluate the span of control needed, it would be necessary to evaluate the average event duration (how much time the supervisor spends solving each problem, on average) and the overall demand for managerial attention.

2.2.3 Typical Organizational Structures

There are a few typical organizational structures. It is not possible to tell which one is better: each is adequate to a certain type of organization and its strategic objectives.

A functional structure "is a design that groups people based on their common skills, expertise or resources they use" (Jones 2010). This kind of people grouping presents several advantages:

- People become more specialized and productive, learning within the team and creating their own norms and culture;
- Supervision is facilitated (supervisors are specialists in same areas as subordinates);

However, the functional structure usually presents several handicaps, especially for more complex companies: large companies that operate in multiple markets or have very distinct products or business process. In such situations, a functional structure might become a struggle. With functional teams, each with their own hierarchy and paradigms, they tend to distance between one another as a company becomes larger. This creates a communication and alignment issue hard to solve (Azevedo 2016).

One common example of this is the difficulty of maintaining two separate departments – sales and marketing – working together efficiently. The most intuitive way of solving this drawback is promoting the integration of functions, combining both departments in one (Jones 2010).

Hence, for more complex structures, companies usually move to divisional structures. In this structure, people and tasks are grouped to form smaller subunits, turning each subunit into a "profit center". These subunits may be product-based, geographic-based or process-based, depending on the problem to be solved.

For example, a product-based structure has the advantage of keeping managers focused on their product and customers and leads to greater division effectiveness. Nevertheless, it may account for a loss of focus on the company overall goals and strategy, making it hard to coordinate all divisions (that can even start competing for resources). Moreover, functions are duplicated along the structure: there are various sales teams and production teams, each for each product (Azevedo 2016).

It is also worth mentioning the matrix structure. In a matrix structure, people are organized simultaneously by function and product. Thus, each employee reports directly to two superiors: a product team manager and a functional manager. This structure has the advantage of creating cross-functional teams, reducing functional barriers and subunit orientation (problems with functional and divisional structures, respectively). It also promotes flexibility in using skilled professionals, moving them from product to product as needed. However, the lack of a well-defined hierarchy can result in conflicts between teams over the use of resources and in defective leadership and structural stability (Azevedo 2016).

2.3 Ensuring Team Alignment in Continuous Improvement – Daily Kaizen

Teamwork may become a problem in organizations if communication is faulty within the team. It is fundamental to keep everyone – from the director to the operators – on the same page and aware of what are the objectives to accomplish.

On the other hand, although many continuous improvement projects based on employees are started, the failure rate is high. This is due mainly to the "lack of understanding of the behavioral dimension" (John Bessant 2001). Consequently, continuous improvement is an evolution that has as key the institution of behavioral routines within the firm (John Bessant 2001)

Kaizen Institute champions that natural teams – that is, the teams that work together every day at the same area and performing tasks for the same goal – should hold regular, short, focused meetings. These are called *Daily Kaizen.* The Daily Kaizen has the objective of giving autonomy to natural teams to solve their own problems and plan their daily work. Moreover, it constitutes the cornerstone of a culture of continuous improvement, not only because it promotes the continual improvement of working standards, but also contributes for the team to disruptively think of new ways of doing things.

At a *Daily Kaizen* meeting, the natural team gathers around a board for a short period – 5 to 15 minutes – and follows a standardized agenda, specifically made for that team, that should cover the following topics:

Presence checklist

At the beginning of the meeting, the Team Leader should check if every team member is present.

Indicators update and analysis

There is a well-known saying: "you cannot improve what you do not control and you cannot control what you do not measure". The team should then keep regular track of the most relevant indicators (4 or 5 at most, to keep meetings focused) and understand its impact on the organization. Kaizen Institute has done projects in several companies that did not do this. In one metal wire company, is was not measured the service level. Once the company started measuring the number of on-time deliveries, it found that almost 40% of all deliveries were either late or failed. In two weeks, this percentage was reduced to under 20%, just because the team now understood what the problem was and could draw solutions for it.

Only by having SMART objectives (Specific, Measurable, Achievable, Relevant and Time-bounded) and indicators that correctly represents them, the team can work its way up to achieve operational excellence. Therefore, if an indicator reveals that a target is not being met, the situation must be analyzed to find the causes of it and a corrective action must be drawn. Also, indicators must be volatile from meeting to meeting (it is pointless using a yearly indicator in a daily meeting, for example).

Visual work planning

The work for the next shift/day/week should be organized with the team at the meeting. Everyone must know what they are in charge for during the next hours and days. A visual work plan, with tasks assigned to people, should be present at the board. This has the advantage of making work imbalances visible: is there workers with too much to handle? Can the team fulfill everything it has to do, or should it ask for help? What are the main tasks and the less important and urgent ones to do? What issues may the team expect to happen?

Deming cycle - PDCA

When analyzing indicators and planning the work, opportunities for improvement will appear. The Deming cycle, also called PDCA (Plan-Do-Check-Act), is an iterative four-step method to support the implementation of improvements. At the meeting – or even outside of it – actions to improve the team performance should be placed by the team members on the board, to be on display for everyone and not get forgotten. An action should be filled into a card which has:

- A short description of the problem;
- A short description of the action to correct it;
- The date when the problem appeared and the dates planned for the action start and end. These actions must be short, well defined and should not have a planned duration of over 1 month. Otherwise, it will get neglected and will not be completed;
- The name of the responsible for the action. The responsible can be from outside of the team if the team is not able to perform the task by itself.

Once an action is established, it will follow these steps, according to with the PDCA method:

- Once the action is validated by the team, it is placed on the “Plan” column;
- When the action starts getting done, it is moved to the “Do” column;
- After the end of it, the results from the action must be checked, to evaluate the benefit of it on the performance of the team. Thus, it is placed in the “Check” column;
- After it gets checked, the action is placed at the “Act” column. If the action was successful, it ends. Otherwise, the team should come up with a new action, based on the experience learned with the last one, to try and succeed this second time.

Other elements

When in need, the *Daily Kaizen* board can have further elements, supporting team meetings. Some examples may be:

- Competences matrix – To detect needed skills of team members in certain topics and support a training program;

- Training program – With a plan of what training will be received by each team member and when;
- Free communication area – To place norms, shift reports, photos of good practices.

2.4 The 7 Muda

Muda is the Japanese word for wastefulness and the 7 Muda model was created by Taiichi Ohno and Shigeo Shingo to explain the different causes of the waste found in organizations (Imai 2012). Everything that does not add value to the final customers is considered waste, as it does not increase the value of the product, only its cost. The 7 Muda are the following:

Overproduction

This is the worst Muda since it creates all the other ones: producing too much too early will lead to excessive inventory, higher lead times and unnecessary use of resources.

Transportation

Moving the product from one place to another does not transform the product, so no value is added. However, transportation adds up costs in an organization: resources employed, investments needed, area used for corridors and higher lead time to deliver goods.

Inventory

Inventory, be it raw materials, work-in-process or finished goods, comprises invested capital that is yet to produce any income. This means space is being occupied and resources employed to produce something that is not needed yet. Also, with a lot of stock to absorb variability, problems and inefficiencies in the supply chain are hidden.

Motion

Operators should have everything they need to perform their job close to them. Every movement a person does that does not transform the product, does not add value and thus deteriorates productivity. There must be a right layout design, sequence of tasks and placement of tools and materials to ensure productivity and ergonomics.

Waiting

If an operator is waiting for a machine to complete its cycle, for material to arrive to him or for another operator to finish his task, he is not adding value. This is a common problem in production lines that are not well balanced.

Over-processing

If a product is more complex, has more features and tighter tolerances than what the customer wants, it over processed. An example of over processing is having processes that are not standardized in which operators spend too much time focusing on small details that the customer does not care about instead of adding real value.

Rework

Whenever a product has a defect, rework must be done. This comes with great costs for an organization: scrap material, need for resources and time to produce new parts, having people correcting defects. Every rework is a waste so conditions to get it right at first try should be met.

2.5 Standardization

Standardizing work consists of establishing a set of norms and tools by which employees are directed to performing a task in a specific, well-defined way. It can be applied in any area of an organization and has the following objectives (Imai 2012):

- Clarifies best practices and share them among employees;
- Create alignment within the organization and labor discipline;
- Creates a way to simplify, measure and improve working methods;
- Reduce variability (one way of working) and waste (the best way known of working).

Standardization is nowadays often viewed as an impediment to innovation. However, it has been shown that even in the most innovative businesses, well-defined standards support employees' daily activities. Management consultants, for instance, are perceived as "change agents" who defy existing norms and lead organization innovation. Surprisingly, consulting firms have embraced standard agendas and methods (Christopher Wright 2011). These standards support knowledge sharing, the processes followed when engaging with clients and communication between consultants.

2.5.1 Workplace organization – Border of Line and 5S

The workplace can also be the object of a standardization process. 5s is a workplace organization tool with the following 5 steps (each begins with the letter "s" in Japanese, hence the name):

- ***Seiri* (Sort)** – The first step is to eliminate what is not necessary from the workplace. This reduces the time spent looking for objects;
- ***Seiton* (Set in Order)** – "Each thing in its place, each place for its thing". Every material must be placed in a well-defined and identified location;
- ***Seiso* (Shine)** – Cleaning and tidying the working area on a daily basis makes problems visible and prevents equipment deterioration;
- ***Seiketsu* (Standardize)** – A standard with best practices on how a workplace should be kept must be created, in order to maintain it;
- ***Shitsuke* (Sustain) –** Everyone in the organization must have the discipline to keep the workplace clean and organized without the need of supervision.

Usually, the first object of 5s is the border of the line, since this is where the value is added. The border of the line should be designed in a way that minimizes the motion Muda and facilitates the usage of the materials needed to do the operation. Also, when it is possible, materials should be provided inside small containers, place at the operator's reach in from of him (see figure 6).

2.5.2 Visual Norms and OPLs (One Point Lesson)

To establish a standard procedure, people must be trained in doing a task in a certain way. To ensure a standard is well established after the training is complete, a norm should be kept and easily available for the worker. The norm must be brief, simple, and visual. There are two types of norms (Vanessa Prajová 2016):

- Management standards – for example, administrative regulations;
- Operational standards – which standardize the way employees work.

A common way of presenting an operational norm is the OPL: One Point Lesson. An OPL presents a specific task in short bullet points along with explanatory images of the process. It should be only 1 page long and be kept at the workplace, to be rapidly consulted by the worker whenever needed.

Figure 6 A correct border of line: 5s applied and materials are in small, easy to reach packages

2.6 SMED – Single Minute Exchange of Die

Changing production series, be it in a machine or a production line, encompasses a period of production stoppage. On top of that, it is common to have productivity losses before the machine stops and after it starts again – be it speed loss or rejection due to quality issues. The setup time can be defined as the time passed between the last good unit produced from batch A and the first good part produced from batch B, at the required efficiency.

SMED is an analysis and improvement methodology to reduce time lost in production series changes (Imai 2012). The reduction of unproductive time presents two large benefits for companies:

- Production flexibility by allowing cheaper, shorter series. This leads to stock reduction and smaller lead times;
- Higher machine real capacity. With shorter setup times, production throughputs can be larger, reducing the need to invest in more machines and reducing production costs.

A SMED approach comprehends a 5 steps method, as presented by Masaaki Imai (Imai 2012). In figure 7 these steps are further explained:

1. Work study at the *Gemba* (shop floor);
2. Separate internal from external work. Internal work includes tasks that can only occur with the machine stopped while external work can be done with a running machine;
3. Convert internal into external work;
4. Reduce internal work;
5. Reduce external work.

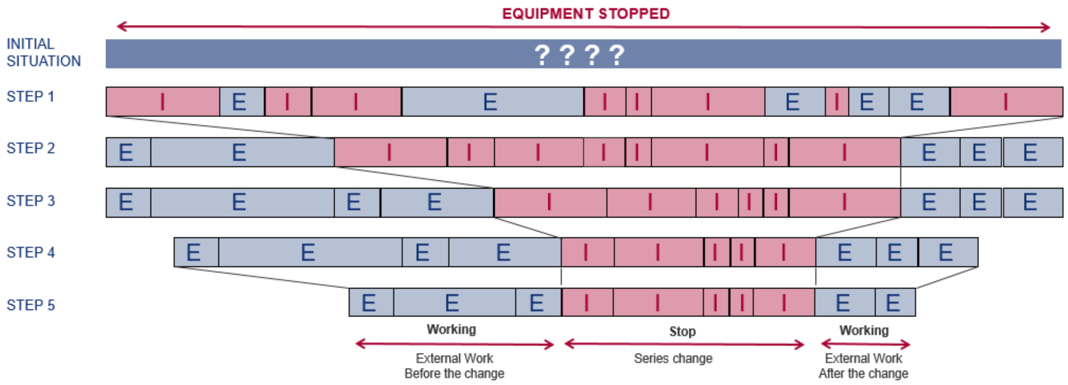

Figure 7 SMED methodology

2.7 Mizusumashi

Mizusumashi – a logistics train or a *mizu* for short – is the operator responsible for all internal logistics operations:

- Replenishment of all components and materials at the point-of-use;
- Pickup of finished goods, empty carton boxes and other materials from the border of line;
- Transportation of all information needed and production orders.

A mizu intends to standardize the internal logistics processes. The common paradigm is to use a forklift that works like a "taxi" (it is called when it is needed) or even having operators getting the materials they need (which presents a huge productivity waste because operators have to leave their working station). On the contrary, a mizu has a standardized route and cycle time, working like a train. A transportation system that is not standardized will lead to higher working variability and lack of productivity. This translates into unnecessary costs with operators and equipment and operational difficulties in supplying what is needed when it is needed (Imai 2012).

Therefore, a mizu concentrates all transportation Muda in it, removing non-value-added activities from operators and increasing their productivity.

3 Initial Situation: Problems and Opportunities

The first weeks at the DP were spent on the shop floor, close to operators and understanding how each team functioned, the relations between teams and the daily struggles. Following the Kaizen methodology, a consultant should, with the team, find the Muda at the *Gemba* (shop floor). In order to do that, the team had been previously formed on Kaizen Thinking and the principles that Kaizen Institute follows.

There were several areas found to be in ineffective and had a chance to be improved. These are presented in the chapters to follow.

3.1 Organizational Structure and alignment difficulties

When the project started, the DP followed a functional organizational structure, where people were grouped according to the similarity of their functions, as presented in Appendix B. The teams were the following:

- Injection team – works 24/7 with 3 shifts. Each shift has a single team leader for 18 operators;
- Injection processes team – works 2 shifts per day, 5 days per week. Each shift has 3 fine tuners (one of which is the Team Leader) and 3 mold mounters;
- Machine maintenance team – works 2 shifts per day, 5 days per week. Each shift has 2 operators. There are 2 operators working a regular shift (from 8 am to 5 pm);
- Mold maintenance team – works 2 shifts per day, 5 days per week. Each shift has 4 operators;

There is also a planning team, a raw materials team and an engraving team. These were not considered in the reorganization of teams at this first stage of the project. The tasks of each operator in each team are presented in Table 1.

This organizational scheme, with support teams only working 2 shifts 5 days per week and the injection team working 3 shifts 7 days per week, had several problems that were noted after just a few days. One issue was the lack of support teams during night shifts and weekends. Therefore, whenever a machine or mold had a problem during the night or weekends, the machine had to be stopped until the morning or until Monday, accordingly. Moreover, because the injection processes team was also not around, a broken mold, for example, could not be replaced during these periods. Because of this, Mondays were particularly hard days, as a lot of problems had piled up during the weekend and had now to be solved by these support teams.

Another big issue was communication between teams and shifts. If for example, a machine has a certain problem that operators should be aware, the machine maintenance team has difficulty in passing on this information, as there is no efficient channel of communication. Each team works almost alone and little information is passed between the injection team and the support teams. Because of this, there are recurring issues that could be avoided with better communication. One example witnessed was a mold guide that broke. The problem had been identified by the process injection team, but information was not passed on – just a talk over coffee with a maintenance operator. A few weeks later, the mold broke and nobody in the maintenance team recalled the issue.

Also – and this is transversal to all teams – there are few standard procedures, best practices or even standard ways of communication. This leads to alignment difficulties between and within teams and to great performance variability: in the DP, it is heard a lot that “each day is different”.

Throughout the next chapters, the problems within each team are analyzed.

Table 1 Tasks per function at the DP

Function	Tasks
Team Leader	Manage team's vacations and days off Assign tasks to operators Solve machine problems Prepare machines for setup
Operator	Packing Trim flashes and separate pieces from sprues Replace other operators when needed Logistical operations
Mounter	Move molds from the preparation area to the machine Mount molds Unmount molds
Fine Tuner	Fine tune molds Retune during production
Mold Maintenance Operator	Clean molds Repair molds in and outside machines Improve molds
Machine Maintenance Operator	Preventive and corrective electrical and mechanical maintenance of machines

3.1.1 Injection Team - A wide span of control and inefficient operators

The injection team leader had an abnormal span of control: he was responsible for 18 operators over an area of around 2000 m^2. His day was spent running around the factory solving machine stoppages and helping operators that were in need. Because of the wide span of control and covered area, he faced a hard time meeting all requests for help, so it was normal to find machines stopped for several minutes.

Moreover, due to this *firefighter* type of job, not much time was left to train operators, audit their work and workplace and improve whatever problems occurred in the facility. This meant that operators felt a lack of leadership: not because the team leader was not good, but because he was not capable of supporting everyone. In Appendix AC, it is found a typical day of a team leader. Throughout the project, the whole day of team leaders was followed several times. Most of the day was spent in fire-fighting activities (see figure 8): correcting mistakes, solving machines stoppages and quality problems, re-planning work. Only 22% of the day is spent training team members, auditing their work and giving feedback and only 5% is spent in teamwork planning. So, only a few of his time was spent in activities that contribute to the improvement of the company on the long run.

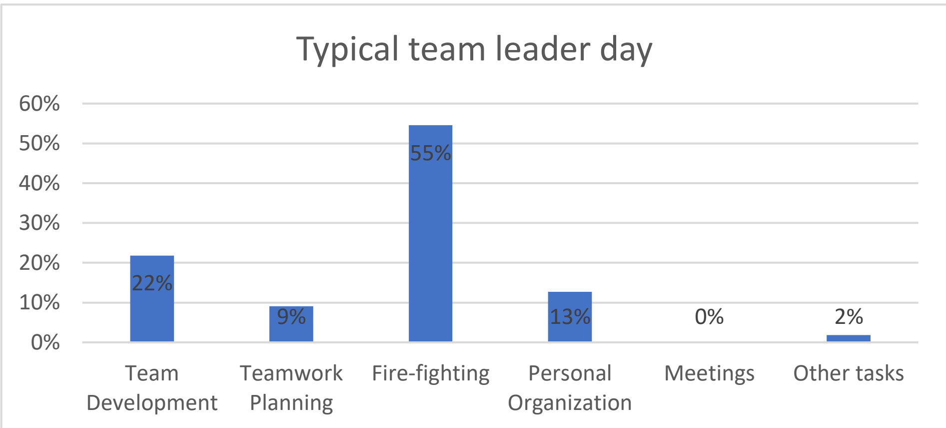

Figure 8 Typical team leader day: firefighting takes most of his time

To make matters worse, there was not a team meeting where problems could be discussed and the work planned. The team leader, based on the information passed on by the team leader of the previous shift, would go around the factory and talked individually with each employee about the problems that may occur on each machine and what recurring defects of the parts he should keep an eye on. So, the team was not aware of the problems happening in their workspace, but just the ones happening at that specific moment in some machines.

Moreover, the DP had too many employees, because absenteeism is high and operators have a low working rhythm. So, throughout the shift, it was common to see operators talking with each other and on their phones, waiting for the machines.

Additionally, there was not a person assigned to replace materials when in short. Usually, the ship responsible (an operator assigned by the team leader to help him in each ship) would go to the warehouse to pick pallets of material. These pallets were placed in each ship, at each end of it. Operators were then responsible for replenishing each machine they were working at with the packing material needed. This meant that they would need to walk around, picking materials and bringing them to where they needed it. To ensure less walking around, they would bring excessive quantities of material to each machine and mount lots of carton boxes, so it would last several hours or even the full shift. It was also the ship responsible the one responsible for transferring the pallets with plastic parts to the warehouse and scan each box, although it was common to see other operators perform this task.

3.1.2 Mold Maintenance

DP has a particularity: for its 46 machines, there are over 1300 molds. That means that, on average, a mold is used once every 3 months. This has serious implications in the mold conditions, as it degrades over time. So, to keep the mold functional, careful inspection and maintenance are needed after it exits the machine and right before it enters it. Although data was not kept over the last few years on the impact mold problems had in the DP, an indicator with the causes for machine stoppages started being followed in 2017, as seen in figure 9. Almost 50% of all stoppages are due to mold issues.

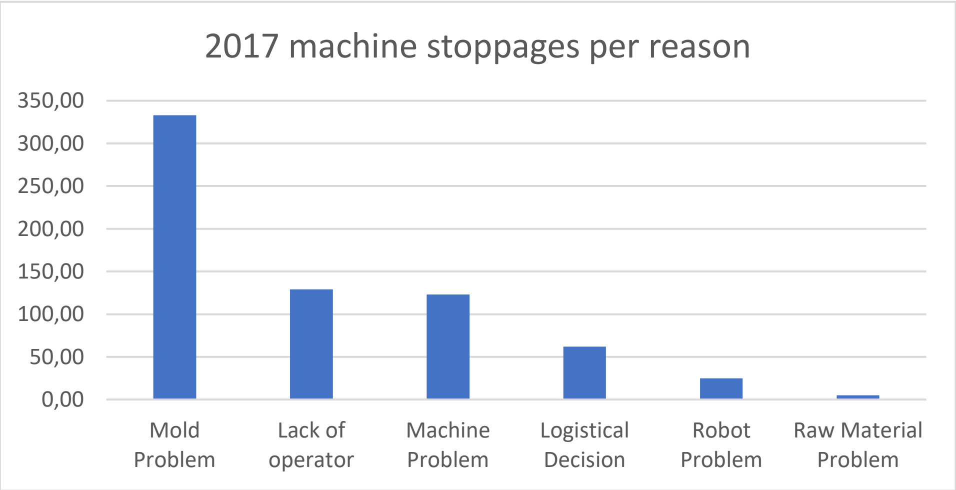

Figure 9 2017 Machine stoppages per reason

Moreover, one can also note that the other main issues are machine problems and lack of operators. The lack of operators usually leads to stoppages during the break periods. In order for the DP never to stop, operators' breaks are taken alternately: only a few at a time, while the others keep up the work. Since absenteeism is high, sometimes during this period there are not enough operators to perform the job, so one or two machines must be stopped.

3.1.3 Injection Processes – The importance of production flexibility and mold changing

An analysis of the DP available indicators was performed throughout the initial situation analysis. These supported the acknowledgment that there were opportunities to improve. Comparing the DP with the benchmarked companies at Appendix E, the DP does not have a great OEE and has terrible setup times. Taking, for instance, the medium size machines: while in DP the average setup time of 2016 was over 2 hours, at the other companies analyzed this time was between around 30 minutes. Even though fine tuning may be stricter at DP than it is in some of the other companies, that alone cannot explain such a disparity – in some companies, the machines have the same model of the same fabricator.

This has great implications in the way EFP works. Not many molds are changed per day – less than 14 out of 46 machines. This is a problem because EFP produces a wide variety of products and, thus, demands high flexibility to the plastics department: the DP produces over 1300 different parts. With such high setup times, it is hard to accomplish that. The DP would have to hire more fine-tuners to change more molds per day, with the drawback of decreasing its efficiency and uprising operational costs. To avoid this, EFP has been following another strategy: subcontracting molds. Therefore, EFP hires external companies to produce plastic parts that the DP does not have the capacity to produce. This held a cost of over 1.5 million euros in 2016, most of which could be avoided it internal production was more flexible.

3.1.4 The Setup process – Cumbersome and without clear standards

It was then necessary to follow several mold changes to understand the process and where the team was losing its time. The process, from planning to mold changing, is the following.

Planning

Each day, the planning team plans which parts are required to be produced, based on the needs from the assembly lines. There is not a clear standard on the rules to follow and so the planners make the decision based on experience and the current stock of each product compared to its need. Then, they evaluate, based on the number of molds that can be changed per shift which molds are a priority. In Appendix X, it is found the average number of molds changed per day per machine type. In 2016, the average number of changes per day was 5,6 for small machines, 5,3 for medium machines and 2,3 for large machines.

There are several molds that are not in-house – instead, they are in other companies which are subcontracted. The planners also have to inform these companies about the material needed for the next few days and weeks.

The planners also decide on the batch size produced by each mold: since not many changes can be made per day and delays are common, the batches are usually quite large and a high safety stock is kept (see Appendix V). This ensures that the assembly lines will not stop production due to lack of parts from the DP, even with recurring delays and mold problems.

Setup Process

The injection processes team then receives in the system the mold changing and fine tune plan for the day. 3 people, with different tasks, take part in the process: the mold changer, the fine tuner and a quality controller. In the flowchart bellow, it is presented what the process usually looks like:

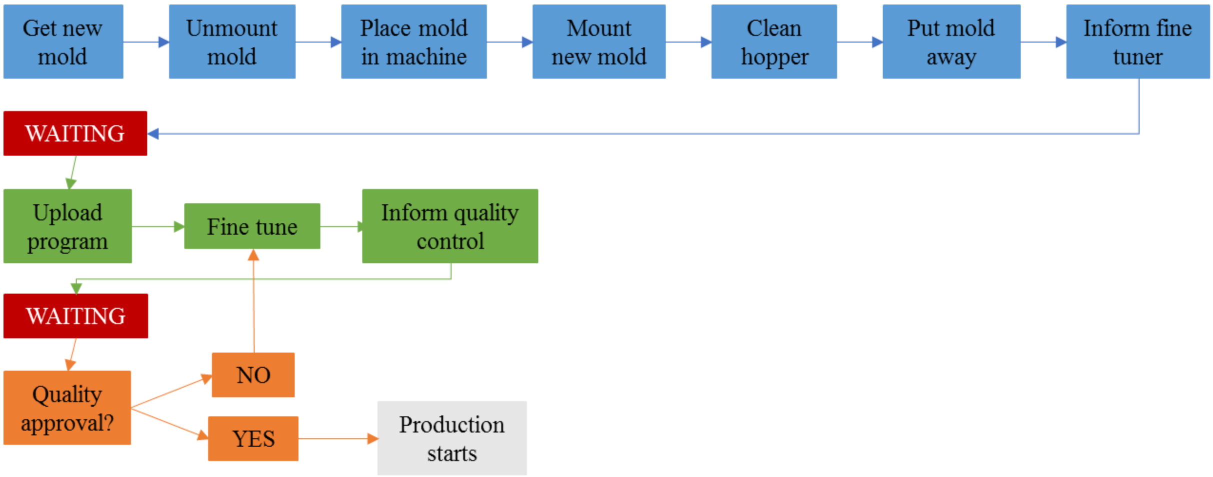

Figure 10 Typical setup process: in blue, the tasks done by the mold mounter, in green by the fine tuner and in orange by the quality controller

Several problems were noted by following several setups:

- There was no standardized process for mounting the mold. The mounter did several external activities (getting the new mold, putting the other one away, get tools from the maintenance area) with the machine stopped. Each mounter worked in a different way, which meant that there was not a "best practice";
- When the mold was set in place, the mounter had to go get a fine tuner that was available. There were not fine tuners responsible for certain machines nor was the work for the day organized: the mounter had to go around the plant looking for fine tuners that were available. Most of the times, fine tuners would be working on a machine, so only after a few minutes (could be 5 or 50 minutes) would a fine tuner be available. Meanwhile, the machine was stopped;
- After fine tuning, the fine tuner had to get a quality controller to approve production. Again, he had to go around the plant (there were 2 quality controllers) to find one. In the meantime, the machine was producing parts: these could already be good but were all considered scrap until the quality controller approval. When the quality controller checked the pieces produced, he either approved production and the setup was finished or he would point out some problem and fine tuning would continue.

The lack of standardization and the fact that 3 people intervened at different points of the setup meant that a lot of time was wasted, which explains the abnormal setup times. It also explains the variability felt: some days 18 molds might be changed while in others only 7 or 8. Because of this, planning was complicated and delays were normal. Moreover, the safety stock kept was quite high, to ensure assembly lines would not stop each time a delay occurs. Also, since molds cannot be changed on weekends and during night shifts, sometimes a mold keeps producing parts way after it hits the production needs. Otherwise, the machine would have to be stopped and the OEE would go down – this is the indicator internally used to evaluate performance, so the DP director is strongly against stopping machines, even if they are producing unnecessary stock.

To make matters worse, the DP director had difficulties keeping fine tuners and mold mounters under control. These are very specialized employees, hard to replace, and so have a relaxed attitude because they know they have a secured job. This problem is enhanced since no indicators or objectives are kept for the team: they have the freedom to do as many setups per day as they wish. This attitude was noticeable: it was normal to find fine tuners and mold mounters drinking coffee and smoking several times during the shift.

3.2 Machine Layout and Workplace Organization

When the project started, the layout of the DP was as presented in Appendix F: there were 3 ships with injection machines, 1 ship for carton and 1 ship for spare parts and various materials. Neither ship 4 or 5 were fully used and took a large amount of space just for storing support materials.

The DP had 46 machines, with clamping forces that ranged from 28T to 900T. Internally, these machines were divided into 3 groups, according to the clamping force (see Appendix G):

- 14 small machines (28-80T);
- 12 large machines (300-900T);
- 20 medium machines (100-280T).

This division was made so each one of the 3 planners would plan production for a type of machines. Moreover, since OEE is related to the complexity of the machine and its size, it was useful to follow this indicator. As it can be seen in Appendix H, the machines were spread around the 3 ships regardless of their size or characteristics. This is because the DP has been continually growing for decades, so the new machines were just added in available spaces as the company grew, without any rule.

The first thing noticeable because of this was the lack of organization. There were machines with almost no space in between them to store any material needed by the operators or for the mold changer to move around when changing a mold, while others had a lot of free space.

Moreover, EFP was going to receive 5 new machines – 2 small ones, 2 mediums and 1 large – in a few weeks and more 5 machines next year (EFP will only get more information about them a few months before hand). Since there was no space available for all 5 machines at ships 1, 2 and 3, it would be necessary to use the upper part of ship 4: this was already prepared to receive machines. Hence, the question laid on how to optimize space usage and take advantage of the space soon to be free. Also, it was important to already define the strategy on how to accommodate the 5 machines coming only next year.

Distribution of materials per machine

There are several molds assigned exclusively to each machine. Each mold produces a different product that, according to its size and fragility, has a specific packaging. There are 4 types of boxes at DP:

- "LEGO" – Large boxes used only for large products produced by the largest machines;
- "Braun" – Small boxes to store the tiniest products. Used only in small machines;
- Small carton – Boxes usually used only in small machines, for small products;
- Large carton – Boxes usually used in medium and large machines.

There are other materials that may be used. For very small components that will be inside coffee machines, quality control is not so tight: a scratch mark and shadows on the surface are not critical. But if a material is shiny and/or easily scratched and is going to be visible in the machine, it must be covered with a sponge that protects it during transportation. It is also common to have blisters: A blister ensures products do not move around and get damaged. Finally, with medium to large parts, they can never just be "thrown" into a carton box. They are usually placed in layers: each layer has *x* components and then a sheet of carton – called separator – is placed on top of them to start a new layer.

On top of the faulty machine distribution along the facility, the space around the machines was badly organized. The first obvious remark was that there were a lot of carton boxes – already mounted, not flat – close to each machine. This was made because in DP there was the paradigm of working faster at the beginning of the shift to mount a lot of carton boxes in advance, so you "*do not need to worry if you need to go to the bathroom or have a coffee*". Operators would mount 8 or 10 carton boxes – which would be good for up to 4 hours, depending on the mold working – and stack them next to each machine. This stacking of carton presents problems:

- The work area is disorganized: in the small space between machines, there is too much material accumulated. If a machine has some problem and needs to be fixed, it is hard for the team leader to move around the machine and solve it;
- Problems are hidden: if for example, there is a leak in a machine, since the floor is filled with material, the operator will not notice it rapidly;
- It is common that, when a mold is replaced, new packing materials are needed. It happened frequently that unused materials next to a machine would have to be transferred to another machine or back to the warehouse, which presented a waste in transportation.

To improve operators' efficiency, the packing materials should be close to them, in an organized manner, so that space is organized and losses in transportation are minimized.

Moreover, due to the machine organization, packing materials are all mixed up in all areas, increasing the work of distributing the materials throughout the ships. If for example, all small machines were together, one would already know that in that area there is no need for large cartons, large separators and blisters nor Lego boxes. The same would go for an area with only large machines: only large cartons and Lego boxes would be needed.

SAN – A delicate material

It was made and analysis of indicators – OEE and rejection – per machine, to check if, within each machine type (small, medium and large) there were any outliers. Immediately, it was noticeable that machines 8, 48 and 53 had had rejection values of over 20% in 2016, roughly the double of the worst large machine. This also had an impact on the OEE, that was an average of 68% in 2016.

Upon further investigation, it was found that these machines only produced water tanks (see figure 11). The water tanks are made of a specific material – SAN (Styrene-acrylonitrile resin), which is resistant to boiling water, making it perfect for such a container. SAN is, however, a very delicate material: contamination is easy and the mold requires special attention. To keep water tanks within quality parameters, fine-tuners and shift leaders must constantly clean the mold and adjust injection parameters.

Figure 11 One of the SAN water tanks produced at DP

Having the 3 machines spread around the factory plant does not provide the “special treatment” needed and machines were constantly stopped while waiting for assistance. Fine-tuners are occupied with setups and the shift leader is busy *fire-fighting*, solving small problems all around DP. To give these machines the attention needed, too much time would be taken so the department almost assumes this problem as a given loss.

Border of Line

Close to each machine, operators should have all materials needed to perform their task. With a closer look, one could see that several opportunities for improvement were present. Operators were constantly looking for materials they needed and were not at hand:

- Cutters to perform occasionally or recurrent rework in parts (trim flashes);
- Adhesive tape to close the carton boxes, both for components and for scrap;
- Labels. The operator should put 2 labels in each carton box with components: one with the shift and operator identification and another with the number of components and their code (to be scanned before transported to the warehouse).

This happens because there is not a specific place for anything: things are just laying around and get lost easily. Moreover, the layout of the border of the line was inadequate, as seen in Appendix K:

- Each component must have a quality check performed – some components have a looser control while others must be carefully checked. For this purpose, quality norms with components samples, displaying the recurring problems and a perfect component, are placed at a quality control stand. The problem is this stand is far from the operator – sometimes facing back at him – so operators rarely use it and mistakes are common;
- To perform quality control and some rework when necessary, good lighting is necessary. Some machines, however, have lamps in awkward places: in the left figure in Appendix K, it is seen that the lamp is very low, so a taller operator easily hits it when leaning forward;
- The working stand is not ergonomic. The operator has two small stands: one to hold the plastic box where components fall (when the machine does not have a conveyor belt) and one to hold the carton box where components are going to be stored. These do not have the appropriate height so taller employees need to lean forward to work. Moreover, it is hard to move them around: this is a problem since operators have to weigh the boxes when full to assure the right number of components.

3.3 Indicators

It is also worth to note that some indicators were not correctly followed and, thus, may not present an accurate description of the initial situation. For once, the machine efficiency was wrongly parameterized: for some molds, the OEE was normally over 100%. This happened because, in some cases, DP did not take into account that a mold could produce 2 pieces at the same time, so the machine theoretical speed was parameterized in the ERP system as half the real speed. In other molds, the situation was not so serious, but still, data was wrongly collected. This situation was corrected throughout 2016 and was fully solved before the beginning of the project presented. However, it shows that comparing the current OEE with the 2016 OEE may not be very accurate.

Moreover, the losses of OEE – availability, performance and quality – are not available. The machines are not directly connected to the ERP system, so there is no way of knowing what are the losses in small stoppages and speed losses. Only 2 measures are accounted for:

- Overall OEE – Comparing total good parts produced with total parts that could be produced;
- Rejection – Comparing parts produced by the machine with good parts that are packed.

The setup times were not followed until 2016. In 2016, the team started following this indicator in an almost manually way: the responsible for the mold change has to go to a nearby computer to begin the setup operation on the system and must close this operation at the end of the setup, after quality approval. This means real setup times may be a bit different that the ones registered.

4 Solutions

4.1 The new organizational scheme

Based on the problems found and on the comparison with other companies, it was clear a restructure was needed. The principles that KI wanted to achieve with a new organizational scheme were the following:

- Team Leaders should have a lower span of control, to have the ability to train, give guidance to their team and solve unexpected problems;
- Setup times must be reduced and more molds must be changed per day to increase production flexibility;
- Support teams – for mold maintenance and changing – must be present at all times.

To achieve this vision, it was necessary to divide the shift into separate teams: having one team leader for 18 people and 51 machines were not adequate as he kept almost no control over what was happening at the DP. So, the first step was to come up with criteria to divide the teams. Two possible solutions stood out: organize teams per ship (1 team per ship) or per machine type (1 team per machine type). A comparison between two hypothesis was carried, as presented in the tables below.

Table 2 Pros and Cons of team division per machine type

Organization per machine type	
Upsides	**Downsides**
Allows for TLs, operators and MMOs to specialize in a machine and mold type, increasing their productivity	Need to redesign the layout and move machines around to group machines by type – involves a cost
Typified mold and machine problems, allows for easier to achieve economies of experience	May be impossible to physicaly separate teams
Easier to quantify operators per team and allocated them	Operators have a more repetitive work - may lead to demotivation
Shorter training time	

Table 3 Pros and Cons of team division per ship

Organization per ship	
Upsides	**Downsides**
Operators work with different types of machines and molds – less repetitive work may increase motivation	Higher training time, since TLs and MMOs will work with very distinct molds
TLs and MMOs become more versatile, gaining know-how on working with different machines, which may come as an advantage, both personal and for the company	Non tiypified problems and very distinct machines may lead to lack of productivity
No need to change the layout – no added cost	

Both solutions presented pros and cons. Discussing both with the DP director, division per machine type was preferred. This was because productivity is the biggest concern and this division is expected to bring productivity up. Additionally, with the acquisition of new machines, the layout would need a reorganization, so moving machines around will happen anyway.

Initially, it was thought to divide the DP into 3 teams: large (300-100T), medium (100-300T) and small (0-100T) machines. The division between each machine type was made to assure machines with similar characteristics stuck together and that teams – considering the current DP situation – had more or less the same size (between 4 and 7 operators per team). However, and as it will be explained in Chapter 4.7, there was the opportunity to physically separate the machines that produced tanks (a very delicate part that is known for having constant quality issues) and pre-assemble them at the DP. For this purpose, it was created a fourth team – the tanks team.

It is also important to refer that a value stream approach was thought of, where teams would be formed based on the parts produced and the assembly line they were destined to. However, the large diversity of parts produced and production complexity would carry unnecessary work and complications.

4.1.1 Functional teams – Assuring 24/7 mold changing and support

Setups as part of the injection team tasks

The next relevant issue to address was the ineffectiveness of the Injection Processes Team, responsible for mold changing and fine tuning. Thus, setup times were too high and the team presented a huge variability – the number of setups per shift varied a lot, making it hard to plan production and leading to constant delays. Moreover, it was noticeable the lack of working pace of the team, with no objectives defined and with a carefree attitude. It was also very unproductive to have two separate people performing different parts of the setup and a third person – the shift team leader –responsible for solving machine stoppage issues.

So, the initial thought was to join the mold changing and fine-tuning activities and concentrate them on a single person. This way, setups are agiler and the waiting Muda (both from operators and from machines) between mold changing and fine-tuning ceases to exist. It was also considered the possibility of eliminating the quality controller and having quality control made by the person that does the setup, but this was not allowed by EFP which was afraid of downgrading its high-quality products.

This would not, however, solve the lack of alignment problem, as there would still be a separate team from the injection team in charge of the setup. So, to give a sense of responsibility to the mold changers and align them with the objectives of the injection team, it was thought of transferring the setup responsibility to the team leader, as it is common at the benchmarked companies. By having all tasks concentrated in one person – mold change, fine tune and machine stoppages solving – and integrating these persons into the injection teams, communication problems are minimized and the injection team no longer depends on another team to perform its job.

On the other hand, by having the setup activity as part of the injection teams' responsibility, it is assured that molds can be changed and fine-tuned on night shifts and weekends (11 more shifts per week). This will largely increase production flexibility by allowing for more molds changes and reducing the average batch size – eliminates situations where the same mold is in production over a full weekend producing way more than necessary.

It is also worth noting that concentrating these tasks on the team leader is only possible thanks to the reduction of his span of control. With smaller teams and fewer machines to supervise, the team leader no longer needs to spend his full shift in *fire-fighting* activities. He also takes more responsibility for his machines, as he becomes responsible for all the process since the mold enters until it leaves the machine.

Therefore, considering the implementation of 4 teams at the DP per shift, there will be 16 TLs, all responsible for setups. This presents a need for training TLs in mold changing and fine tuning: before the project, the injection processes team only had 12 operators (and some of them only knew how to perform half the setup).

Support teams over weekends and night shifts

As seen before, almost 50% of all machine stoppages and 60% of machine stoppage time are due to mold problems[2]. If there was a problem the TL cannot fix on a Friday night, for example, it could only be fixed on a Monday morning. On the contrary, if a machine stops because there is a lack of operators or because there is a problem with raw materials, usually the stoppage time is quite small. Also, when a machine is stopped for logistic purposes it cannot be considered a problem of the injection team, but a planning problem.

This way, the majority of machine stoppage time – besides setups – could be solved if molds were in good conditions and faced no problems. Like stated before, the DP has the particularity of having a low mold rotation, which leads to a higher degradation of the mold and a constant need for small maintenance operations.

At the beginning of the project, the mold maintenance team focused mainly on corrective maintenance, fixing constant mold problems whenever they existed. The mold maintenance team, the injection processes team leaders and the DP director all admitted the need of improving preventive maintenance to reduce mold issues. So, two needs were identified:

- Before a mold enters the machine and right after it leaves it, a checkup should be made and the mold should be cleaned and lubricated to return to its initial state;
- Since molds are changed 24/7, there should always be someone available to perform preventive and small corrective maintenance whenever necessary;

Following these principles, the team restructuring plan was set. Some mold maintenance operators should be integrated into the injection team – for now on called MMOs – according to the same rational followed for setups (improve alignment and the sense of responsibility). The MMO should be aligned with the TL on which molds are going to be changed during each shift to clean and lubricate them. They are also able of performing small corrections that can be made with the mold still on the machine. The MMOs are not responsible, however, for improving the molds or correct major issues that imply a mold disablement for several days. For this corrective maintenance, a smaller mold maintenance team is kept as is, working 2 shifts, since it is not worth the personnel cost increase of having it performed 24/7.

It is still unclear how many MMOs are needed per shift because no data on the time needed to perform preventive maintenance was kept. Therefore, at this moment, it is not established if there will be one or more MMOs per team or even MMOs shared between teams.

Finally, the assumption that preventive maintenance will decrease mold problems was not confirmed. It was taken as true the assumption that the slow mold rotation increases the need for preventive maintenance and that the current lack of it is the major cause of constant mold problems. This assumption must be confirmed when a pilot team is set in place: only if at the pilot team, mold problems decrease, it can be assumed that the MMO figure is an advantage.

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[2] The machine stoppage time per reason only started being followed in 2017 and it is not very reliable. The stoppage time is registered manually by the TL. Sometimes, he only notices the problem a while after it happens or forgets to write the time when it is fixed, so the time registered may not correspond to the reality.

4.1.2 The Pilot team – proof of concept

This deep organizational change could not be made all at once. To prove the concept, first, a pilot team had to be tested. The roll out for the other 3 teams can only take place after results prove the model advantages. Besides the Pilot Team, the remaining DP continues to work in a similar way as before – besides some alterations that affect all the department.

The small machines' team was chosen as the pilot team. This choice was based on two factors: ease of implementation and potential impact on the DP. Therefore, small machines are the ones that produce the largest variety of parts. On the other hand, small mold changes are the easiest, so a SMED workshop is easier to perform and the TLs need less training and experience before assuming the position. Thus, the impact of the potential improvements is high and the time-to-success is lower than it would be with larger, more complex machines.

Another restructuration of the DP injection team was made with the implementation of the mizusumashi. However, this is a transversal figure to all DP teams and will be explained in Chapter 4.5.

The Team Leader

For each, shift, a team leader was chosen for the small machines' team. The choice was made by the DP Director with the support of the injection processes team leaders and the shift team leader. Together, they analyzed which injection processes' operators had the best people skills and youth was preferred. After assigning them the new position, a training program took place: KI taught them the Kaizen Principles, gave workshops on leadership and management and tours to other companies. Shift team leaders were a helping hand to guide them through their first weeks and months.

Based on the principles presented, a standard work instruction was created for the team leader (Appendix W).

The Mold Maintenance Operator

Like stated before, it is not clear the number of MMOs needed for the pilot team. One MMO was assigned per team, as it seemed the minimum necessary. Since preventive maintenance was a clear issue and the team lacked experience, a training program was started meant to establish working standards and set criteria to follow when cleaning and lubricating molds. This training was given by an external entity to EFP, experienced on the subject.

Moreover, the MMO also has some other responsibilities with his team, as shown at the work instruction at Appendix Y. For example, during breaking hours, when there is at least 1 less operator at the team, the MMO must help, if necessary, the injection operators. He must also help the TL with the setup preparation.

Thanks to the train given and to the specialization of an operator per shift in the task of mold cleaning and lubrication, the number of molds for small machines cleaned and lubricated per day is continually increasing: it increased from 5.5 molds cleaned per week to 14.5 (see figure 12). Currently, almost all molds that enter a machine are cleaned and lubricated. This is expected to bring down mold problems.

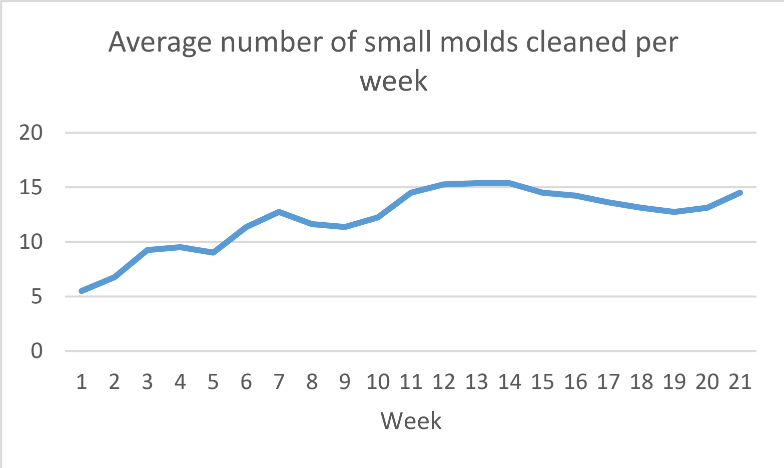

Figure 12 Average number of small molds cleaned per week

The Operator

The only major shift at the operator standard work (see Appendix Z) is due to the need of operators helping the TL with mold changing. So, training was given to them during the SMED workshop, explained in Chapter 4.4.

Besides that, the major focus regarding operators was on correctly determining the number of operators needed for each team. At the beginning of the project, the over-dimensioning of the DP was clear: the working rhythm was abnormally low as there were too few machines per operator.

Team Sizing – Evaluation of the saturation of the operators

A study to determine how many operators were needed was then carried. This study was based on the operators' saturation analysis. The saturation of an operator is defined as follows:

$$\text{Saturation} = O_{CT}/M_{CT} \tag{4.1}$$

Where:

O_{CT} is Operator Cycle Time
M_{CT} is Machine Cycle Time

The O_{CT} is given by the full amount of time the operator must spend with each piece produced by a given machine. The M_{CT} is the amount of time that machine takes to produce each piece. Thus, this ratio gives the amount of operator time a certain machine requires. If for example, the saturation of one machine is 0.3, that means that 1 operator has 30% of his time occupied at that machine.

The machine cycle time is already parameterized, and it depends on the mold that is in production. So, the first step was to get the cycle times of all molds entering in each small machine. The second step was to evaluate operators cycle time. This was done by filling in a table, where each line looked like the one at Table 4.

Table 4 Operators' saturation evaluation

Machine	Mold Number	Cycle Time (s)	Quantity per box	Assembly (s)	Quality Control (s)	Rework (s)	Flash removal (s)	Packing (s)	Box preparation (s)	Total (s)	Saturation	Priority of measurement
6	1338	47	78	0	3	0	0	2,6	0,76	6,43	0,14	High

Since there are almost 600 molds for small machines, it would be unfeasible to evaluate the operator cycle time for all of them. From these 600 molds, 50 molds correspond to over 50% of the overall production time planned for 2017. Hence, these 50 molds were established has “high priority” and the O_{CT} was only measured to these[3].

From this, the number of operators per team is estimated as follows:

$$\#\text{operators} = \sum_{k=1}^{n}(\text{Sat}_k) = \sum_{k=1}^{n}\left(\frac{\sum_{i=1}^{m}(S_i \times t_i)}{\sum_{i=1}^{m}(S_i)}\right) \quad (4.3)$$

Where:

n is number of small machines
Sat_k is the weighted average saturation for machine k
m is the number of molds entering at machine k
S_i is the saturation of mold i
t_i is the expected production time of mold i during 2017

Thus, Equation 4.3 uses the weighted average saturation per machine to estimate the number of operators needed for the pilot team. The weighted average was preferred since it gives more weight to molds that will spend more time in production during 2017.

Based on this evaluation, the number of operators needed would be 2,3. Thus, it was established that this team should have 3 operators: before the project, there were 4 operators at this area. So, not only it is possible to reduce the team, but also the 3 remaining operators have spare time to aid the team leader with mold changes.

4.2 Workspace Organization – More ergonomic, efficient and organized

5s are a cornerstone of Kaizen and the continuous improvement thinking. With an organized border of line, clean workspace and easy access to the materials needed to perform the job, operators become more efficient and motivated. To improve the problems at the workspace detected, several measures were taken:

New border of line – ergonomic and organized

The space around each machine was organized to fulfill two objectives: on the one hand, there should be the fewest material possible between the machines, to facilitate the TL access to the machine in case of any problem or to change molds. On the other hand, the operator should have everything he needs close to him: the only traveling done should be from one machine to another. Moreover, ergonomics was considered to create a workspace where the operator feels comfortable and can be as productive as possible.

In order to achieve this, 3 structures were designed and built (see Appendix L):

- A quality stand, placed in front of the operator, with good lighting at a higher place. The old quality stand was far from the operator and took a lot of space between machines. Now, to perform quality control, the operator does not need to move to another place as the sheet with quality warnings and sample parts are placed within an arm’s reach in front of him. Moreover, almost no floor space is occupied since this structure is above the machine’s conveyor. The quality stand also has a specific place, at the right side, for placing the adhesive tape (one per machine and a spare one), the cutter and the labels

[3] Saturation was also measured for machines not part of the small machines team. This is still an ongoing process, as the same analysis is necessary to roll out this model to the rest of the teams

needed. This way there is a specific place for all materials the operator needs. Finally, the lamp is at a higher place so taller operators no longer bump their heads against it;

- 2 structures with wheels. One, in front of the operator, to retrieve the parts that come from the machine. Also, beneath it, it is a larger carton box to put the rejected parts (this box no longer occupies floor space on the side of the operator). Another structure, on the right side, has the box where the good pieces go and, beneath it, there is space for a second carton box (not present in the figure in Appendix L). These are taller and lighter than the previous structures, making them more ergonomic. Also, they are easier to move around, making it easy to push them to the scale or just to move them whenever needed (to free space when the mold is being changed, for example).

Furthermore, the space around the machines was standardized: floor marks specify the place where each thing belongs, making it easier to keep everything organized. It was also reinforced that there cannot be any carton boxes on the floor around the machines: there should only be two unfolded carton boxes, one in use and the other beneath it on the structure created.

Carton cars – easier for the mizusumashi, easier for operators

To help to organize the space and to assure no unnecessary material nor carton boxes were on the floor between machines, a structure was created to keep flat carton boxes, separators and other materials. Thus, the mizusumashi (see Chapter 4.5) replenishes material only to the structures presented at the Appendix N. These structures are placed at chosen locations close to operators – there is one of these for every 4 machines (for small machines) and for every two machines (for medium and large machines).

These not only allow to keep the space organized, but also present other advantages. For once, they have wheels and are light so are easily moved if necessary. Before, when materials were on the floor or on top of pallets, it was much harder to move things around. On the other hand, it helps keep a maximum stock level: now, it is not possible to stack unlimited material on the floor. There is only as much material in the workspace as it fits into these carton cars. These cars have a dimension large enough to keep materials that last over half a shift, so the mizusumashi only needs to have two replenishment cycles.

4.3 Daily Kaizen – Aligning teams and improving communication

In parallel with the workspace organization and team reorganization, it was also created meetings for each team. As explained before, when KI arrived at the DP, there was a profound lack of alignment between and within teams: no indicators were followed, work was barely planned and operators were disconnected from their job. Moreover, with the team restructure that was taking place, it was important to keep everyone on the same page: otherwise, the mindset changes KI wanted to establish would not be successful.

Hence, following the Kaizen Thinking, regular meetings were established for every team at the DP. The first step was to establish, with each team, the board that would be central for the meeting (all boards can be seen at Appendix J). In figure 13, the board of the pilot team is presented. With each team, the key indicators were identified and a schedule for each meeting was set. It was also created the area for visual work planning, an area for the PDCA and a free area where competence matrixes and training programs are placed whenever it seems fit. At the same time, team leaders were formed on the Kaizen Principles and on how to guide meetings.

Following this, it was necessary to create tools to allow teams to follow indicators. Many indicators were simply not kept – such as the reasons for machine stoppages or how many molds were changed per day. Other indicators were kept but the team did not have access to them – like the OEE. So, together with the IT team at EFP, the ERP was prepared to give automatically some of these indicators. When this was not possible, Excel sheets were prepared so each team leader could easily, throughout the shift, follow all relevant indicators.

Figure 13 Daily Kaizen - Pilot Team (small machines)

After each meeting was established, the KI team had to follow them throughout several weeks. The purpose was to keep training and helping team leaders guiding the meeting and encourage team members to participate and present improvement ideas. Typically, the hardest part is to create an improvement mindset where the team correctly uses the PDCA to reflect on the problems affecting it and come up with solutions.

Thanks to these regular meetings and Daily Kaizen boards, now each team has a moment to analyze its situation, discuss solutions to improve their daily work and come closer to accomplish the objectives set. Moreover, the work planning is easier and the TL does not need to realign each team member as often during the shift. Also, a daily meeting was created with the TL of all teams at the DP. This meeting, longer than the rest (20 minutes long) is essential to keep all teams aligned, smooth communication between teams and give visibility to problems affecting each team. At the moment, all teams correctly used their boards and, after the initial resistance, most teams understand the importance of the boards and the utility of them.

4.4 SMED workshop – Decreasing setup time

After the pilot team was formed, the TL already knew how to change and fine tune molds and was ready to perform the task and lead the team. It was expected that by centralizing all setup processes in just one person instead of two the setup time would go down. However, it became worse, taking longer than the average values of 2016 (see Appendix R, table 11). This had four main reasons:

- The new team leaders were still young and lacked the experience older fine tuners have. Although changing the mold is straightforward, fine tuning it requires experience;
- The TLs were performing the setup all by themselves, while before the mold changers would sometimes help each other to change a mold faster, diving tasks between them;
- There was no standardized way of performing the setup: each team leader did it in a certain way. As it can be seen in the figure 14, the difference between the fastest and

the lowest shift was large: over 30 minutes in February. The lack of standardization also meant there was still a lot of machine downtime that could be avoided.

- The slowest TL had a lack of training. The supposed to be TL of shift B left the company, so an operator had to be rushed into training just a few weeks before taking charge. Although he is smart, young and motivated, only with experience will he reach the best times from shift A.

The experience factor would only come with time, so there was not much to be done on that side. However, everything else could be improved with a SMED workshop.

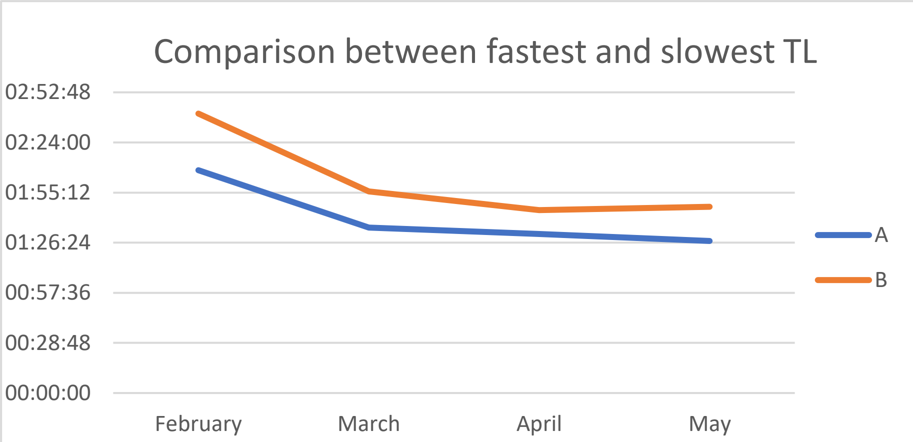

Figure 14 Comparison between fastest and slowest TL in setups

4.4.1 The workshop - methodology and opportunities found

The first step of the workshop was to understand the initial situation. After following several setups performed by each shift, the table presented at Appendix S was created. Here, it was clearly identified what is internal and external work. As it can be seen, there were several external tasks done in the middle of the mold changing process. Just by eliminating this, doing them before the machine is stopped, it could be saved over 9 minutes. Moreover, the TL spent too much time looking for tools at his tool box, moving around the machine performing separate tasks in no specific order and had a different approach each time a mold was changed. Also, sometimes materials were missing in his tool box, so he had to go to the maintenance area to get them.

Consequently, the first step was to move external tasks to the beginning or end of the mold change, to reduce the machine stoppage time. The second step was to organize the tool car, standardize the process and clearly identify in what order things should be done and the materials needed for each step. This way, several small improvements were made with the internal work.

At this point, the standard work present in the table 13 of Appendix T was created. Here, internal and external work is already separated, small improvements in internal work were done and procedures were standardized. The objective time for the setup was reduced from 78 to 67 minutes.

Getting operators involved

The next step was to get operators to help in the simpler tasks of the setup. At the companies with the best setup times (companies A, B and C, at Appendix E), operators help with the mold change and, at company C, they are entirely responsible for the mold change: it is only needed a fine tuner to end the setup process. The advantage of this is having 2 people working on the setup in parallel, either performing one task faster or two separate tasks. At the DP, it was decided to have only 1 operator per shift helping the TL. This is due to a lot of resistance by some ladies and older gentlemen to perform these tasks that were considered by them “not part of their job”.

As it can be seen at the table 14 of Appendix T, the operator was involved in the process by performing simple tasks: placing cramps on the mold from one side of the machine while the TL place them from the other side, calling the RMM (raw materials mills responsible) to engage the raw material tube and cleaning the hopper. The hopper is the place where the raw material is, in the form of pellets, before entering the machine. Thus, since different materials cannot be mixed to not create defects, cleaning the hopper is a long process that has some particularities and must be well done. For this purpose, a visual work instruction, present at the Appendix Q, was created to guide the operator throughout the process. This norm was the support for the train given to the operators and for the process standardization.

With the help from the operator, the objective setup time was reduced to just over 46 minutes.

Other improvements

Standardizing processes is not the only improvement that can be made. Improvements in the molds and in the machines, can and should be made to make the setup easier for the team leader. Thus, several improvements were identified that could bring the setup time down. These are not yet done:

- Faster fixation cramps on the molds;
- A centering system, with just a crack and a ledge on the machine, to easily center the mold;
- Pen drives at each machine with the latest program update for fine tuning of each mold, to reduce fine tuning time – this will have an impact of several minutes since currently fine tuning is made “from scratch”.[4]

4.4.2 Results

As presented in Appendix R and at figure 15, the setup time average time was reduced from almost 2 hours and 30 minutes before the SMED workshop to just 1 hour and 32 minutes. Although it was a large improvement from the 2016’ average of 2 hours and 9 minutes, it is still way above the objective of 45 minutes. There are two main reasons for this:

- Even though training was given and operators already know how to perform their setup tasks, they do not help the TL most of the times. At this point, resistance is still visible and operators do not want to help with setups. Their biggest argument is that they do not have time to do that. This is due to the low working rhythm still visible at the DP;

[4] This was something seen in companies A, B and C that largely reduced fine-tuning times.

- Mold changing usually does not take longer than the objective time. However, fine tuning is very variable: it may take a few minutes or almost one hour. This is due to the lack of experience of TL and will improve with experience and with the existence of pen drives on each machine.

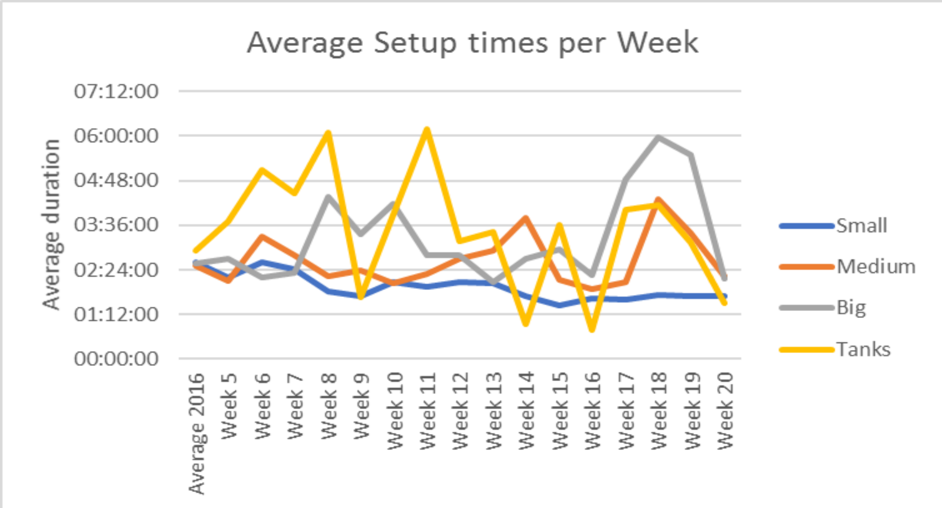

Figure 15 Setup time evolution per machine type

Another great improvement was the elimination of variability. As seen at figure 14, the setup times for the machines not included in the pilot team have a huge variability, making it almost impossible to plan production since there is no way to anticipate how many molds will be changed in each day. As for the pilot team, after the workshop setup times have stabilized. Finally, the workshop allowed for the gap between the fastest and slowest TL to decrease, from over 30 minutes to just about 15 minutes.

4.5 Mizusumashi - Concentrating transportation waste

A transversal figure supporting the work of all operators at the DP, regardless of their team, is the mizusumashi. Following the Kaizen Thinking, the internal logistics Muda (transportation) should be concentrated in a person, dedicated to replenishing operators with the materials they need and retrieve finish goods to the warehouse, among other tasks.

Even before listing all activities the mizu performs, to check how many mizu were needed, it was asked the team leaders of each shift to appoint someone for the job and an eventual replacement (for the days the mizu was not working). The criteria used were: someone young, hard-working and energetic, keen on having a relevant task at the DP and that understood the Kaizen principles. The next step was determining what were the exact tasks and the time the mizu took on each task, to train him in performing them.

Together with the injection team, a list of the tasks the mizu should perform was established:

- Transfer pallets with plastic parts to the DP warehouse;
- Replenish pallets to a specific place on each ship;
- Replenish large carton boxes and large separators;
- Replenish small carton boxes and small separators;
- Replenish Braun boxes, blisters and sponges;
- Collect carton boxes with scrap and transfer it to the raw materials warehouse;
- Scan boxes.

At the beginning of the workshop, each mizu was trained on how to scan boxes, how to solve unexpected issues (like one box disappearing from the system) and where materials were and should be placed at the DP and at the warehouse. To do this, the operators that usually performed these tasks and KI helped the mizu, following him around during the full shift and helping him when he did not know what to do or had too much work to handle.

In parallel, it was defined the number of cycles the mizu should have and if a second mizu was necessary. Although a mizu should work on a well-defined cycle, at the DP it is tricky to establish such a cycle: it is not possible to know exactly when each pallet of plastic parts is ready to be transferred to the warehouse nor when each machine needs more material. The cycle is based on estimates and so it can wrong.

Accordingly, the time the mizu spent on each task was measured. Thus, each time the mizu was followed throughout an entire shift, a sheet like the one presented at Appendix AB was filled. This is called *shadowing* and gave a general sense of the time spent on each task and what other tasks the mizu was asked to perform occasionally (such as bringing consumables like duct tape to operators, solve problems or organize the workspace). With this template, it was also evaluated how much time the mizu spent with Muda – activities that do not add value or that should not be done by the mizu – and a spaghetti diagram was made, to evaluate if the route followed by the mizu was appropriate.

At this point, it was used a hand pallet truck to perform the job. The results are presented in the table 21 in Appendix AA. As it can be seen, the mizu could not perform all the tasks alone, or else he would not have time to complete all of them. The shift has 450 minutes (8h minus 30 minutes break) and all the tasks took over 510 minutes. So, several tasks – like collecting boxes with rejected parts and retrieve some pallets – were done with the help of operators. Moreover, every shift the mizu spent some time solving unexpected issues that made this problem even worse.

This could not happen. So, based on the conclusions gathered, several small improvements were made to allow the mizu to complete all tasks. These include:

- Placing the printer that was in ship 1 and was hardly ever used near the warehouse exit, where the mizu placed the pallets with plastic parts;
- Increasing the mizu's training in solving problems so he could be more independent and spend less time asking for help;
- Help the mizu create a more standardize route to decrease the time spent replenishing materials;

This allowed him to complete all tasks during the shift. However, time was still short. It was then made available by EFP the opportunity for the mizu to use a stacker if needed. By testing the stacker, is was measured, as seen in the table 21 in Appendix AA, that it was now spent only 411 minutes performing all tasks. So, there is still room for the extra work when more machines are at the DP and for other additional tasks that will appear in the future (mainly related to the tanks' assembly at ship 4). Moreover, using the stacker is more ergonomic and less tiring.

In a continuous improvement spirit, additional small changes are constantly being made to the mizu's work, making it more functional and reducing Muda.

4.6 Visual norms

One of Kaizen principles it to have visual norms and standards to keep everyone following best practices. Thus, when creating a new norm, the best available practice is defined as standard and it is placed in a convenient place where an operator, when performing that task, can easily and rapidly consult if in doubt.

When establishing the pilot team, to ensure high performance, several norms and standards were created. For example, at Appendix P, it is presented the work instruction for machine 32. Although the operator is already experienced in performing his tasks, having on the machine a visual reminder of how he should perform helps him do “things the right way”. At Appendix Q, it is found the work instruction for cleaning the hopper, created after the SMED workshop, to guide the operator through this new task (explained at Chapter 4.4).

Besides work instructions, there are several visual norms that reinforce how space should be organized. These were not created right at the beginning of the project, but only after a few weeks for the cases where it was seen that the team struggled to keep standards.

As Chapter 4.5 points out, the mizusumashi replenishes materials to carton cars spread around the plant. Sometimes, materials were placed on the side of it on the floor or were arranged in odd ways. So, as presented in Appendix N, a visual norm is kept above all carton cars to show how the material should look on the car. Another example is presented at Appendix M: when changing molds, sometimes the TL placed the mold in the middle of the aisle. This is not allowed due to safety reasons because it blocks the aisle. So, a space on the right of each machine, which the TL identified as suitable for him, was created to place the changing molds, with the visual norm placed above it (this can also be seen at Appendix L).

In another example, every day at 2 pm, the DP receives an email with the “urgent materials”, that is, materials needed as soon as possible at the production lines. Whenever a box or pallet is produced from one of these parts, it should be immediately placed at an “urgencies area”. Only a certain amount, specified in the email, is urgent. However, the production director warned the DP that often there were 2 or 3 times more pallets than needed there. This happened due to bad communication between shifts: the mizu from each shift considered the material urgent, even if there was already enough quantity at the lines. To mitigate this problem, the sign presented at the Appendix O was created. This is placed on each machine when it starts producing an urgent part. There, it is identified the urgent quantity and the mizu continuously updates the already transferred quantity. Only after the new email arrives, the following day, will this sign be removed. This way, shifts easily communicate among themselves.

4.7 Layout Redesign – more space, better organization

4.7.1 Tanks dedicated area

With the arrival of the 5 new machines, a reorganization of the layout was mandatory. There was not enough space in the 3 ships used at that time. Knowing this, the DP had already prepared the top end of ship 4 (currently unused) to receive machines: it already had the electrical installation, the raw materials tubes necessary and the bridge to place the molds into the machines. So, the question was: what machines should be sent to ship 4?

The obvious first answer would be to place the new 5 machines on ship 4, as it was easier than moving around machines from the other ships. However, this did not make sense, according to the team division KI wanted to implement – as explained in Chapter 4.1. Moreover, this was the opportunity of improving the layout of the whole facility and tackle some problems the DP was facing.

As explained in Chapter 3.2, tanks are a very delicate part to produce due to the material used (SAN). So, having the 3 machines spread around the layout was a problem since it was difficult to keep an eye on these machines at all times. With the arrival of one more tank machine, this problem would be enhanced. Hence, the team thought of taking advantage of the layout reorganization happening and the new team organization to enhance the focus on tanks and reduce rejection and machine stoppages.

The 4 tanks machines were all placed on the upper end of ship 4 (see Appendix I). This way, tanks have a dedicated space and, as explained at Chapter 4.1, a dedicated team and team leader capable of changing molds, fine tune and solve unexpected issues. Furthermore, since this is a closed area, steps were taken to make this a "clean area" to reduce rejection problems: the area is closed and separated from the other areas to avoid contaminations, operators and whoever visits the space must use hair net and, together with the procurement team, only plastic boxes are used to eliminate the dust that carton boxes carry[5].

This reorganization also brought up another opportunity: tanks produced at the DP follow, afterward, this process:

1. They are packed into carton boxes at the DP;
2. At the engraving area, they are unpacked, engraved and packed again;
3. At a pre-assembly line they are unpacked, added some components to make it ready for entering the final product and packed again;
4. Finally, they are unpacked and enter in the final product.

There was a lot of repacking and transportation happening: all of them are losses (Muda) and should be minimized. Moreover, with this delicate material, rejection happened at all these stages, making the overall rejection at EFP very high.

With the tanks' machines now in ship 4, there was a lot of free space around the machines (see Appendix I). With this free space, it is possible to engrave and pre-assemble the tanks at the DP, eliminating steps 2 and 3. This means less Muda, less rejection and fewer operators are needed in the aggregated process. The implementation of pre-assembly and engraving of tanks at the DP is taking place at the moment, with the construction of the border of line, the supermarket and the team definition. There is no reliable data on the gains it is going to provide nor the number of operators needed at the tanks team (although first insights show 1 person per machine will be enough and tests are showing rejection is significantly reduced).

These layout changes were done during the Carnival week since it is a holiday at Torres Vedras and EFP gives its employees 2 vacation days. This way, production impact was minimized.

4.7.2 Future layout

To accommodate the 5 machines coming next year, more changes are going to be made. Discussing with the DP director, it was noted that ship 5 (see Appendix F) was mostly unused and had a lot of scrap materials that could be thrown away. It was considered, however, that production should be kept all close and would not make sense to have some machines at ship 5 while the carton warehouse is at ship 4.

So, machines should be placed at the bottom end of ship 4 and the carton warehouse would be moved to ship 5. In accordance with the teams' formation explained at Chapter 4.4, it makes sense to have similar machines as close as possible: not only it is easier for the teams that have to cover a smaller area, but also it makes it easier to standardize the border of lines, the layout and the way of working at each area of the DP.

Therefore, it was analyzed which group of machines could be moved to ship 4. There are too many medium machines to be moved to ship 4, so this hypothesis was eliminated. On the other hand, the bigger machines at ship 1 are so large that makes it impossible to have another machine in front of them. As for the small machines, they could all be placed at ship 4 and still have some extra space, so this was the hypothesis chosen.

[5] this is possible since these boxes are only used internally and do not leave EFP. The procurement team analyzed the data and found, in the long term it is beneficial to eliminate all carton. Steps towards it are now being taken to eliminate carton in all areas of EFP.

A layout for this future situation was designed at AutoCAD (see Appendix AD). By having all small machines at ship 4, the area occupied by them is reduced from 600 m^2 to 440 m^2. More importantly, while currently the machine at the end of ship 2 is at 60 m from the machine at the bottom end of ship 3, with all small machines at ship 4 the linear distance is only of 25 m, so the team is closer and the TL can easily "keep an eye" on his machines.

Not only the space occupied is smaller, but the ship will also be more organized. At the Appendix AD, one can see the normalized border of line, as explained in Chapter 4.2, but more organized than currently due to the added space. Also, the extra space improves mold changing, as the team leader can move around the machine easier. Moreover, it was added an area (see bottom left of Appendix AD) to store robot parts. These are constantly being used so it makes sense to have them close to the team instead of keeping them far away in the maintenance area.

Finally, at the top end of the ship one can see pallet spaces to keep consumable materials: pallets, carton and/or plastic boxes, blisters, separators. There are two purposes for this:

- Reduce the mizu's travels to the warehouse, that is now located further away in the ship;
- Make the mizu's job easier, so he can keep the space organized and perform his job better. With more machines, the DP will produce more and he will retrieve more pallets to the warehouse, leaving less time to replenish materials. With these pallet positions, he reduces the time needed to replenish the materials to all machines.

Moving all small machines to ship 4 will forces a considerable part of DP to stop production. To avoid this, these changes are going to be made in August, when EFP is closed for vacations. Currently, the carton warehouse is already at ship 5 and ship 4 is prepared to receive machines.

4.8 Results – Discussion and opportunities to unfold

Overall, EFP is satisfied with the impact KI is having at the DP and the results obtained with the pilot team. The new role of the team leader is proving to be a success, as the OEE increased, the number of molds changed per day increased and variability is lower for the pilot team, compared with the rest of the DP.

Starting with setups, as presented before, the variability in setup time is now much lower and the average setup time suffered a 25% decrease after the SMED workshop was performed (see Appendix R). This was only possible by concentrating the setup responsibility in a single person, standardizing the processes and having operators helping with small tasks.

However, as seen in Appendix X and in figure 16, the setup time reduction did not show an increase of mold changes per shift. In 2016, the average number of setups per shift of small machines was 2.8 (2.9 if August, a clear outlier, is excluded). Currently, considering April 2017 – as the team improved every month since February – the average number of setups per shift in small machines is 2.8.

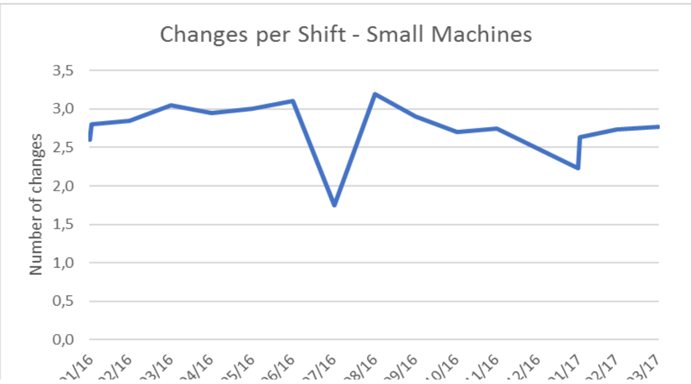

Figure 16 Number of mold changes per shift - Small machines

This is explained because, with the creation of autonomous teams, the responsible for mold changing has several other responsibilities. So, during the shift, there is not one person fully dedicated to mold changing and/or fine tuning. The TL must also do tasks that involve managing his team: help operators, give them feedback, solve machine stoppages.

As seen at table 5, the total amount of time spent per shift changing molds is far smaller than it was before and the TL has 2 hours and a half (considering 30 minutes for a break) to dedicate to other tasks. In 2016, not only setups were less efficient, but the lack of productivity by the mold changing team was also noticeable. With the conservative assumption that only 1 full time equivalent (FTE) was spent on mold changing of small machines, there was still a lot of spare time. However, like already emphasized, the injection processes team worked at a very slow, carefree rhythm, which explains the almost 1 hour of unproductive time.

Table 5 Time spent in mold changing activities per shift at small machines

	Small Machines (28-80T)	
Year	**Time spent changing molds (per shift)**	**Time for other tasks**
2016	06:03:03	01:26:57
2017	04:14:57	03:15:03

However, the team reorganization allowed for far more molds to be changed per day and per month: there was an increase from 5.6 to 8 mold changes per day. This is thanks to the fact that with the team reorganization now molds are changed 3 shifts per day instead of just 2 and on weekends.

This had an immediate impact on the average batch size. As seen in figure 17, the batch size for small machines has been continually reducing for over 1 year. In 2016, it got stagnated at around 20 000 parts per production batch. With the number of setups performed at that time, the planning team had no way of going bellow this number. With the pilot team in place, the average batch size was just around 13 500 pieces over the last two months, a decrease of over 30%.

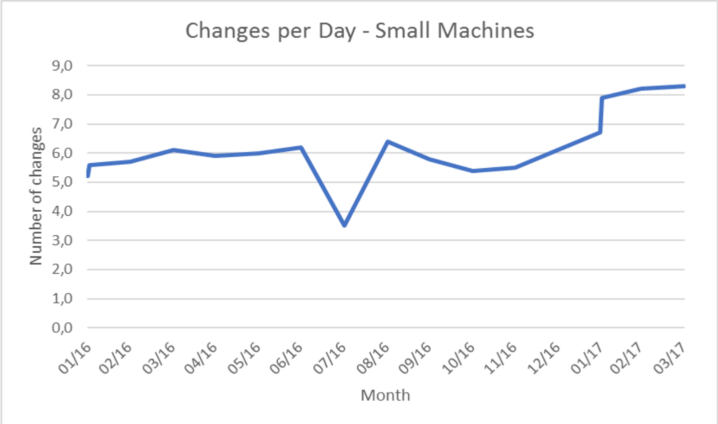

Figure 17 Number of mold changes per week - Small machines

This has not yet, however, translated in a visible stock reduction, as expected. This is mainly a planning problem: there are not well-defined minimum and maximum stocks, nor replenishment points. Planners rely entirely on their experience to plan production. Naturally, this leads to several planning mistakes and over production and excessive stock are still problems that need to be address. The smaller batches will be a fundamental tool to reform the way of planning.

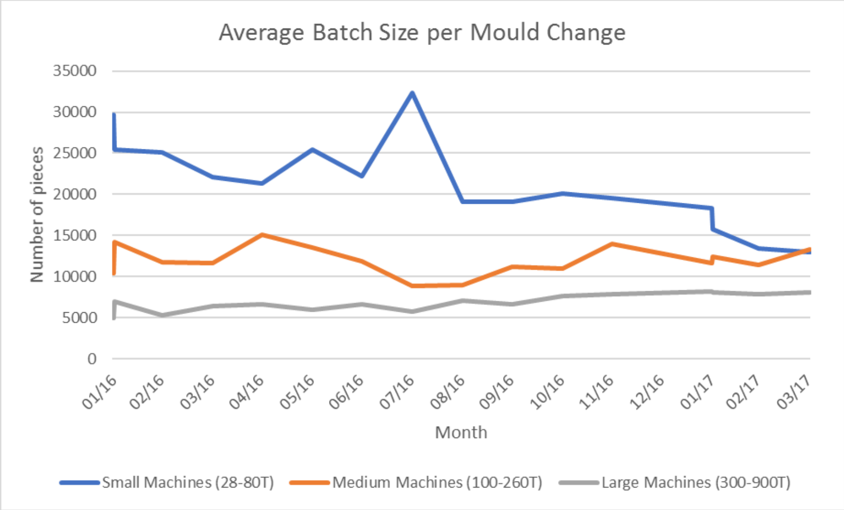

Figure 18 Average batch size per mold change per machine type

OEE evolution

The most important indicator for the DP is the OEE. As presented in the figure 19 and at the Appendix U, the OEE for small machines grew slightly: from a 2016 average of 83% to 86%, even though more setups are now performed (each setup represents a machine availability loss). This means that it was possible to keep production efficiency while simultaneously increasing its flexibility. At table 6, the losses in OEE per reason are presented. It is only possible, at the DP, to calculate losses due to mold changing and due to rejection, so speed losses and other availability losses are not discriminated.

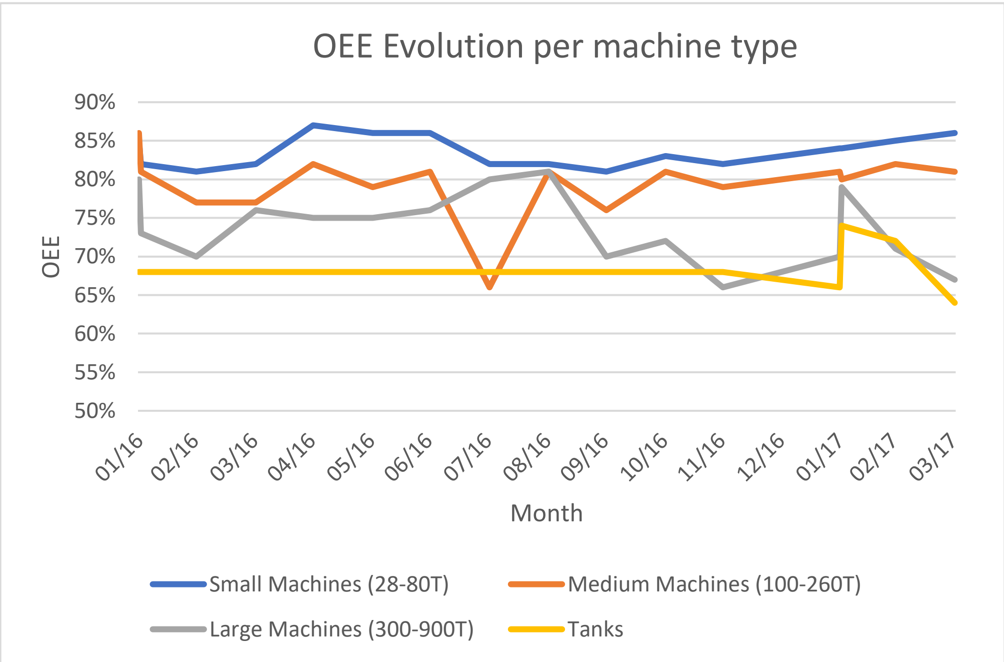

Figure 19 OEE evolution per machine time per month

As presented at table 6, even though a lot more molds are now changed, the impact mold changing has on OEE is roughly the same as before. Also, rejection stayed stable. The only major difference is at the “other reasons” category. This includes speed losses, micro stoppages, mold and machine problems.

Table 6 OEE Losses per reason - 2016 vs 04/2017

Month/Year	OEE	OEE Losses: Due to mould changing	Due to rejection	Other reasons	Number of small machines
2016	83,3%	3,6%	1,5%	11,7%	14
abr/17	86,0%	3,3%	1,6%	9,1%	16
Difference	2,7%	0,3%	-0,1%	2,6%	

It is still early to assume if this positive difference was a direct result of the new team organization or if it was just casual variability (there were months in 2016 with a higher OEE). If, throughout the next months, OEE keeps stable or even increases, then it will be fair to assume that the creation of autonomous teams has had a positive impact on the team efficiency. Moreover, by analyzing the evolution of machine stoppages per reason, it will be studied if the MMO figure has had any impact on the results achieved: is the OEE increase explained by fewer stoppages due to mold problems?

Finally, the pilot team reveals far less OEE variability[6]. The processes standardization is, therefore, increasing the predictability of the team efficiency and sustaining it.

Subcontracting

Since EFP increased the production at the assembly lines, when compared to last year, the need for plastic parts increased. The DP has more demand, both in volume and in flexibility, than it did last year. So, even though production flexibility is higher, the need for subcontracting molds increased and so did the expenses with it, for all machine types. As a fair way to compare mold subcontracting needs from last year and from this year, this was not accounted for when analyzing the success of the project.

4.9 Future steps

Now that the pilot team is in “smooth sailing” the DP is ready to roll out the creation of more autonomous teams. It is expected that in one year all 4 teams will be formed and fully operational. Additionally, more changes are taking place at the DP:

- 5s are being implemented at the area of the support teams (raw materials warehousing, mold maintenance, machine maintenance and engraving);
- A new figure – the DP Lean Manager was created to sustain the changes that are being made by KI. Thus, a machine maintenance operator that stood out for his hard work and will to improve was chosen by the DP Director for this task. He is currently being trained by KI on Kaizen principles;
- Mold improvements are being made by the mold maintenance team to improve setups and further reduce them;
- A new team will be in place when the DP reorganization is finished: the processes injection improvement team. This team will have just 2 operators – the current injection processes team leaders – and will be responsible for the continuous improvement of the injection processes and to support the team leaders, improving their work;
- A project with the planning team was already started to rethink the way production planning is made and assure a stock reduction.

[6] It appears that the tanks team has the lowest OEE variability during 2016. However, this indicator was no tracked during that year and it was cumbersome to retrieve data from the ERP for all months. So, the average of December of 2016 was assumed as the OEE for the rest of the months of that year.

5 Conclusion

The objectives set at the beginning of the project are mostly not completed at this early stage of it. The workplace already suffered some changes and the border of line is now more ergonomic and standardized. Also, the layout has been redesigned – as far as it could be, before having information on the machines to come next year – and now space is more organized.

As for the pilot team, the establishment of clear working standards and the team reorganization allowed for a setup time reduction of 25% and a small efficiency improvement of 3% with the saving of one operator. However, OEE has not yet increased to 90% as expected neither did the number of setups per day doubled. More importantly, the added production flexibility has not translated yet into a stock reduction and mold subcontracting is still highly needed.

Tanks' dedicated area

The layout reorganization not only allows for the inclusion of more machines at the DP, but it was also used in favor of the team reorganization KI instituted. However, some changes' advantages are not yet validated. Creating a dedicated, clean space for tanks machines has not produced any results in terms of rejection reduction so far. It is expected that when a dedicated team for that ship is fully established and pre-assembly is done at the DP, there will be significant savings thanks to an efficiency increase and the decrease of operators needed. Still, the creation of the tanks dedicated space, by itself, did not succeed.

Layout of ships 1, 2 and 3

Since it is still not clear the size of the 5 machines that will be received in early 2018, the layout of the other ships is not closed and. Some remarks on the subject are necessary:

- If small machines arrive, will they be placed on ship 4? There is still room for 2 more machines, with a few adjustments. However, one may also consider the hypothesis of using the less occupied ships 2 and 3. This would change the view on team organization as small machines could be integrated into the medium or large size machines teams;
- If another machine like the ones of ship 1 arrives, where will they be placed? These cannot be put in front of another machine, so it would likely be placed in a different orientation (like the larger tanks machine in ship 4);
- With the apparent impossibility of placing medium and large machines at different areas of the DP, would it make sense to make teams based on area instead of machine size, as initially thought?

Questioning machine size based team formation

The layout organization directly impacts teams' formation, as a team should be all concentrated at a certain area and without the presence of other teams at that area. This is not only to help the team leader manage his team, but also to avoid issues between teams sharing the same space. The purpose of having each team assigned to a specific area is to ensure the attitude of "this is my area, I must take care of it and make it the best".

The tanks team and the small machines team are already concentrated in a smaller location. However, the large and medium machines teams will be dispersed over ships 1, 2 and 3, when created. This means operators will cover quite a large area and team leaders will have difficulty covering problems from all machines, even though the span of control is smaller. Therefore, the problems that exist today at EFP may still exist within these teams in the future. The decision to form machine type based teams may not be correct and should be re-evaluated soon. Alternatively, it may be preferable to create teams per ship. With this division, the medium and large machines teams would be divided into 3 teams, one for each ship and 1 new team leader per shift would be necessary.

Autonomous Teams

The creation of the pilot team may be questionable. If the SMED workshop was done with the processes injection team instead and a reorganization just of this team was carried, would results be any worse? This was not tested and the hypothesis was eliminated right from the start, as the lack of alignment and sense of responsibility would be an issue difficult to overcome.

Moreover, it is unclear what expenses or savings the creation of autonomous teams will bring in terms of personnel cost. If, in one hand, the team re-dimensioning and reorganization will reduce the number of operators and eliminate the processes injection team, it is also true that more team leaders will be needed and the figures of the MMO and the mizusumashi were created. It is expected a personnel reduction (see tables 7 and 8), but this assumption is very rough and may not hold true when the other teams are formed.

Table 8 Initial Situation at the DP

Function	Number per shift	Number of shifts	Total
Operators	18	4	72
Mold Maintenance	4	2	8
TL	1	4	4
Mounters/Fine-tunners	6	2	12
Total	**29**		**96**

Table 7 Expected future Situation at the DP

Function	Number per shift	Number of shifts	Total
Operators	14	4	56
Mold Maintenance	2	1	2
MMO	3	4	12
TL	4	4	16
Mounters/Fine-tunners	1	2	2
Mizusumashi	1	4	4
Total	**25**		**92**

The rational followed was not a cost cutting one, but rather a resource allocation one: support activities such as mold maintenance and mold changing and fine tuning are key to keep a high performance at the DP. On the other hand, there were too many operators and their productivity was low. With the DP reorganization, the operators' efficiency improved – thanks to the layout and border of line redesign, the work standardization, the existence of a mizusumashi and the closer support by the TL – allowing for a reduction on the number of operators needed.

Thus, to assure higher efficiency, the new team organization gives more relevance to the support activities by taking them as key tasks of the injection team and increasing the time dedicated to them.

Further challenges

There is still visible resistance to the new way of working. In the near future, close supervising and training of operators is still necessary: in setups, in team meetings and in the establishment and maintenance of an organized workspace. The DP lean manager will be a crucial figure to help with this task and assure the project continuity when the project ends.

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Appendix A: EFP Organizational Structure

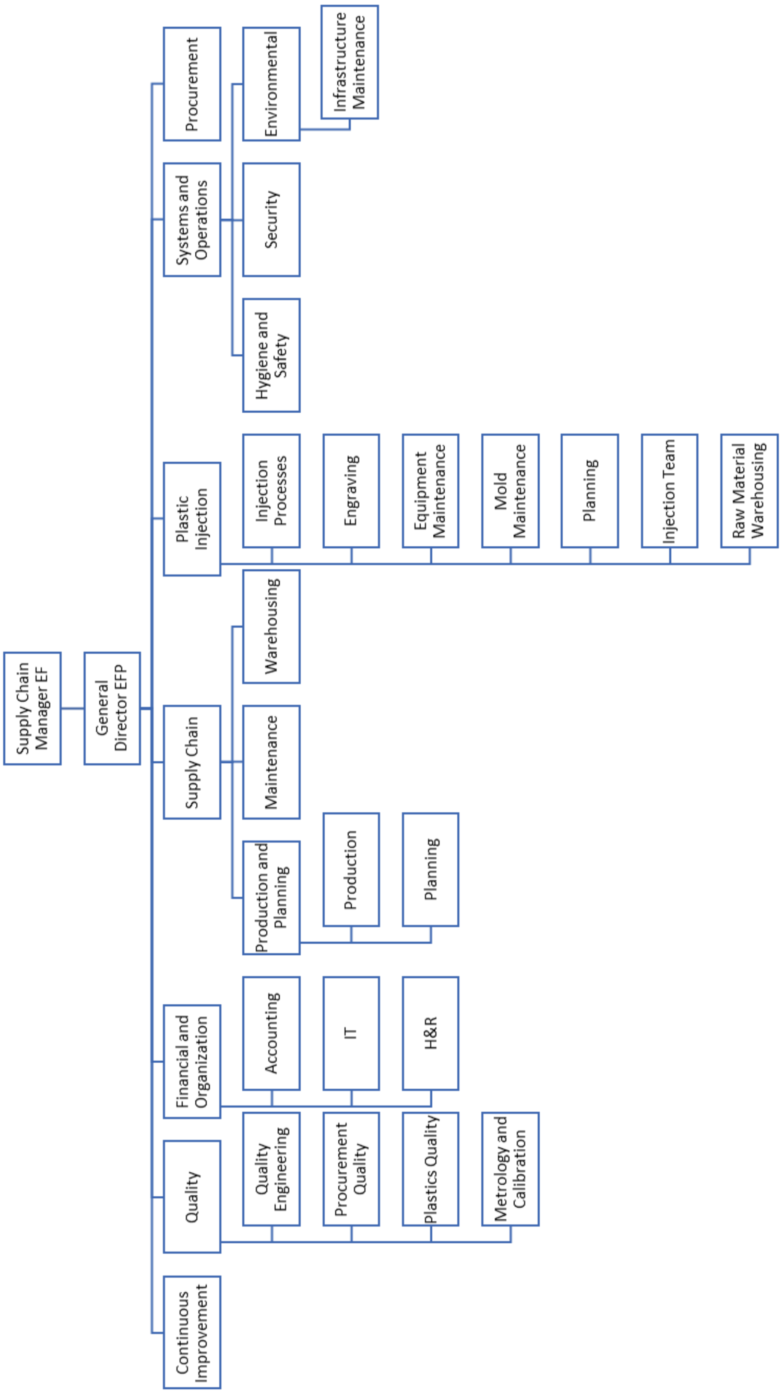


Figure 20 EFP Organizational Structure

APPENDIX B: DP Organizational Structure

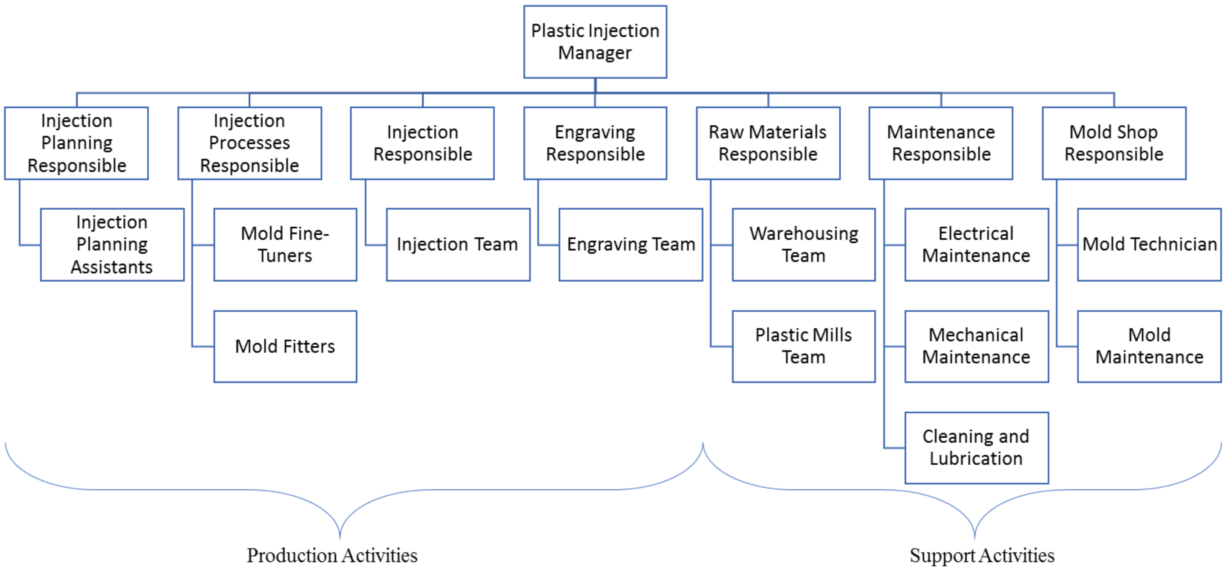


Figure 21 DP Initial Organizational Structure

APPENDIX C: EFP Plant

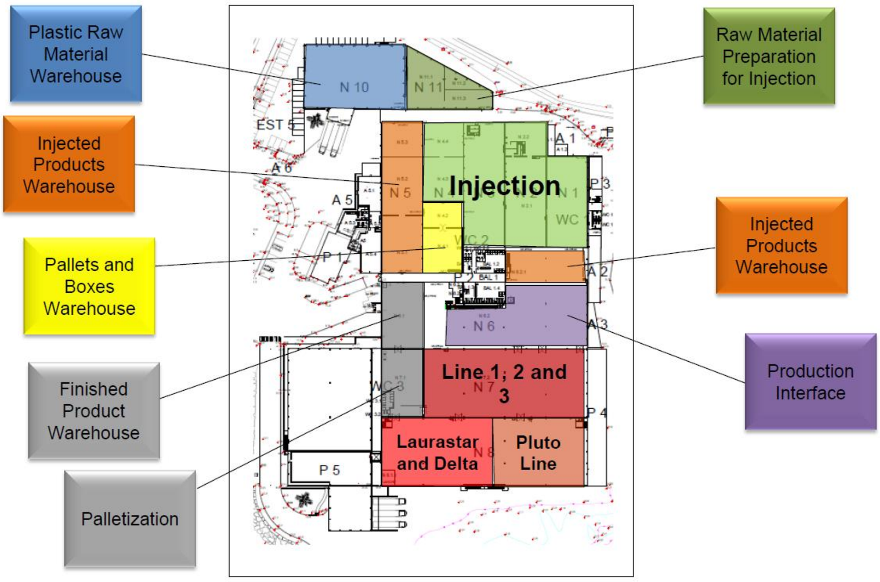


Figure 23 EFP Plant - 1st Floor

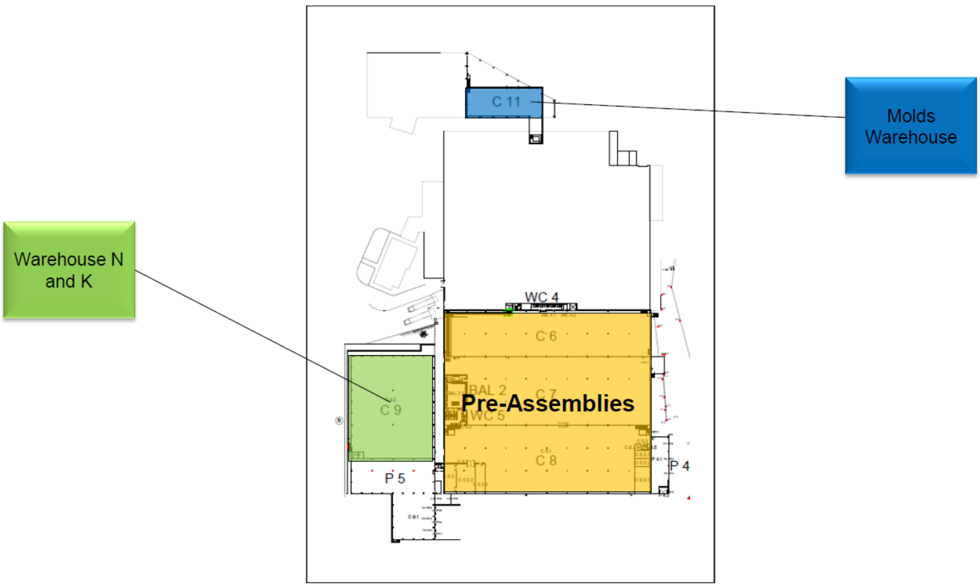


Figure 22 EFP Plant - Basement

APPENDIX D: New DP Organizational Structure

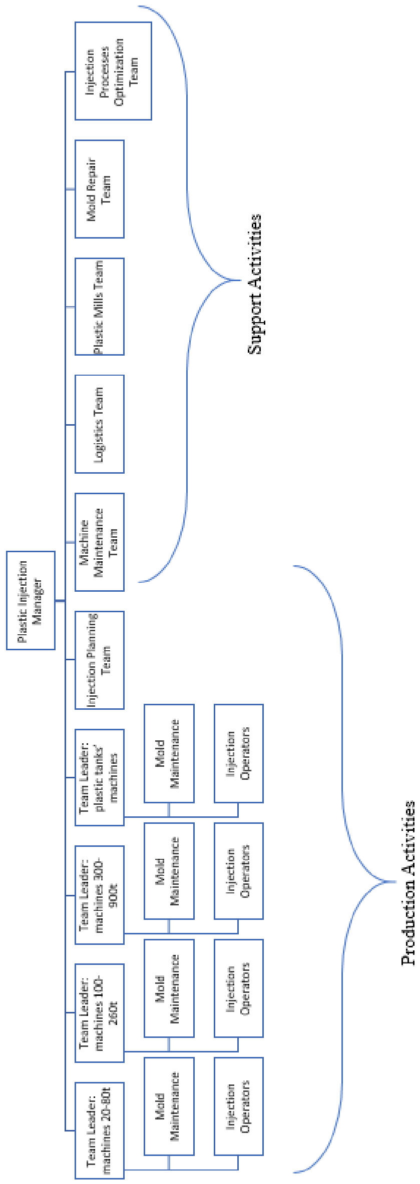


Figure 24 New DP Structure:
Multidisciplinary Injection Teams

APPENDIX E: Comparison between plastic injection molding facilities

Table 9 Number of machines per tonnage in each injection plastic facility analyzed

	No machines			
Company	**0-100T**	**100-300T**	**300-1000T**	**>1000T**
EFP	14	21	10	
A			25	5
B			16	10
C	29	23		
E	4	13	11	1

Table 10 Characteristics of each plastic injection facility

			Mold Maitenance	No machines per operator				No machines
Company	**Operators**	**Team Leaders**	**Operators**	**0-100T**	**100-300T**	**300-1000T**	**>1000T**	**per team**
EFP	18	1	8	3,5	3	1,5		46
A	10	3				3	3	9 to 12
B	12	3				3	3	9 to 12
C	4	1	5	14,5	11,5			52
E	14	3	8	4	2	2	1	9 to 11

Table 11 Comparison between performance indicators of plastic injection facilities

	Setup Time				OEE				
Company	**0-100T**	**100-300T**	**300-1000T**	**>1000T**	**0-100T**	**100-300T**	**300-1000T**	**>1000T**	**Comments**
EFP	02:09:00	02:14:44	04:23:47		83%	79%	75%		
A			00:28:00	00:35:00			85,0%	85,0%	
B			00:28:00	00:35:00			85,0%	85,0%	
C	00:35:00	00:35:00			86,70%	86,70%			Only accounts for losses in performance and availability
D	01:05:00	01:05:00							This company also works with a more delicate material, which has more problems and a more difficult setup (around 90 minutes)
E	01:15:00	01:30:00	01:30:00	01:50:00	66,00%	60,00%	60,00%	57,00%	This companies produces lenses and some other delicate pieces, so there are constant quality issues.

APPENDIX F: Plastic Injection Department – Initial Situation

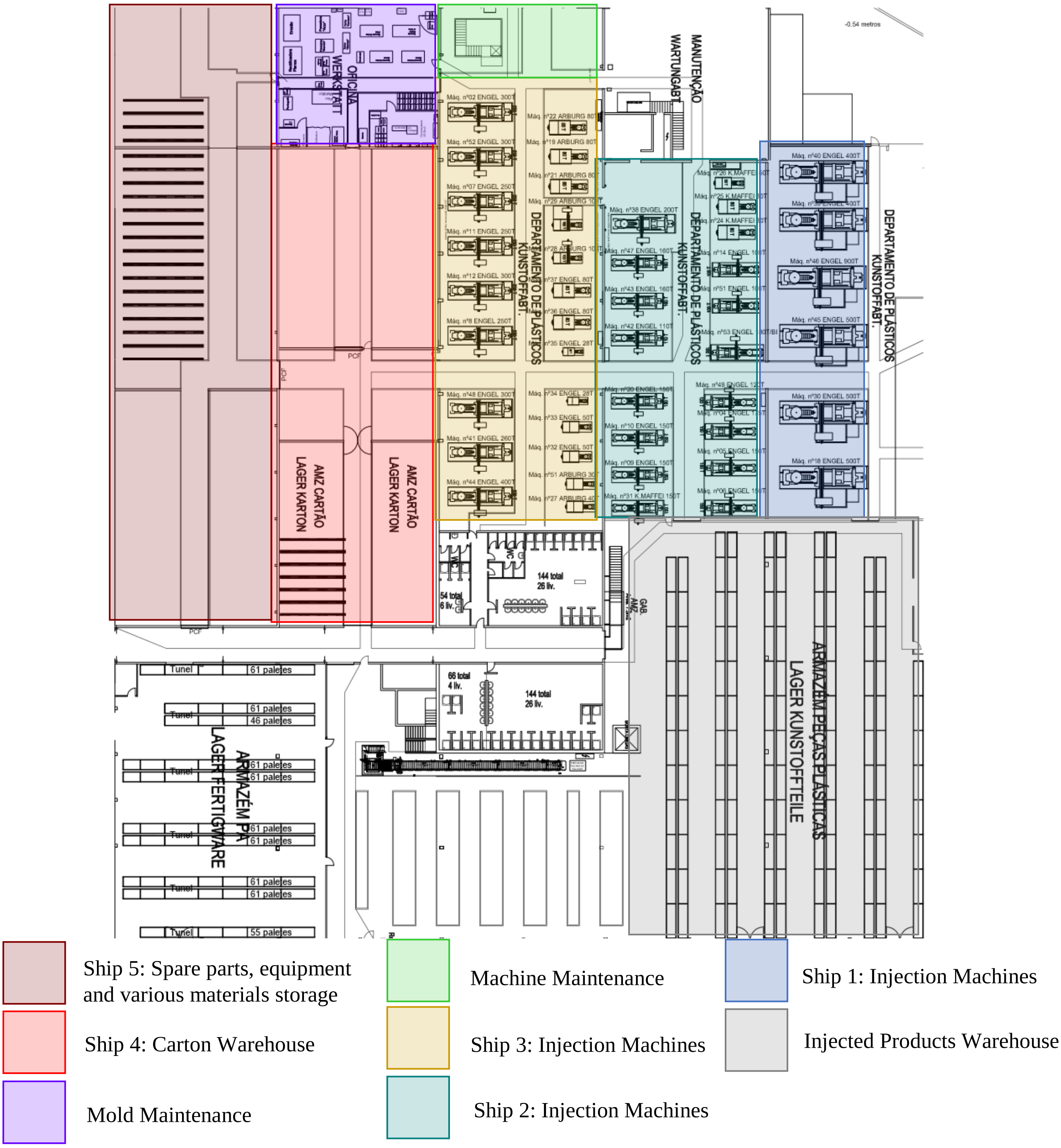


Figure 25 Injection Department

APPENDIX G: Machine Numbering and Type

Table 12 Machine numbering and types at DP. In green, it is represented the new machines (not present at the beginning of the project)

Number	Type
2	Large
12	Large
18	Large
30	Large
39	Large
40	Large
44	Large
45	Large
46	Large
52	Large
4	Medium
5	Medium
6	Medium
7	Medium
9	Medium
10	Medium
11	Medium
14	Medium
20	Medium
28	Medium
29	Medium
31	Medium
38	Medium
41	Medium
42	Medium
43	Medium

Number	Type
47	Medium
49	Medium
51	Medium
56	Medium
57	Medium
19	Small
21	Small
22	Small
24	Small
25	Small
26	Small
27	Small
32	Small
33	Small
34	Small
35	Small
36	Small
37	Small
50	Small
54	Small
55	Small
8	Tanks
48	Tanks
53	Tanks
58	Tanks

APPENDIX H: Machine Layout – Initial Situation

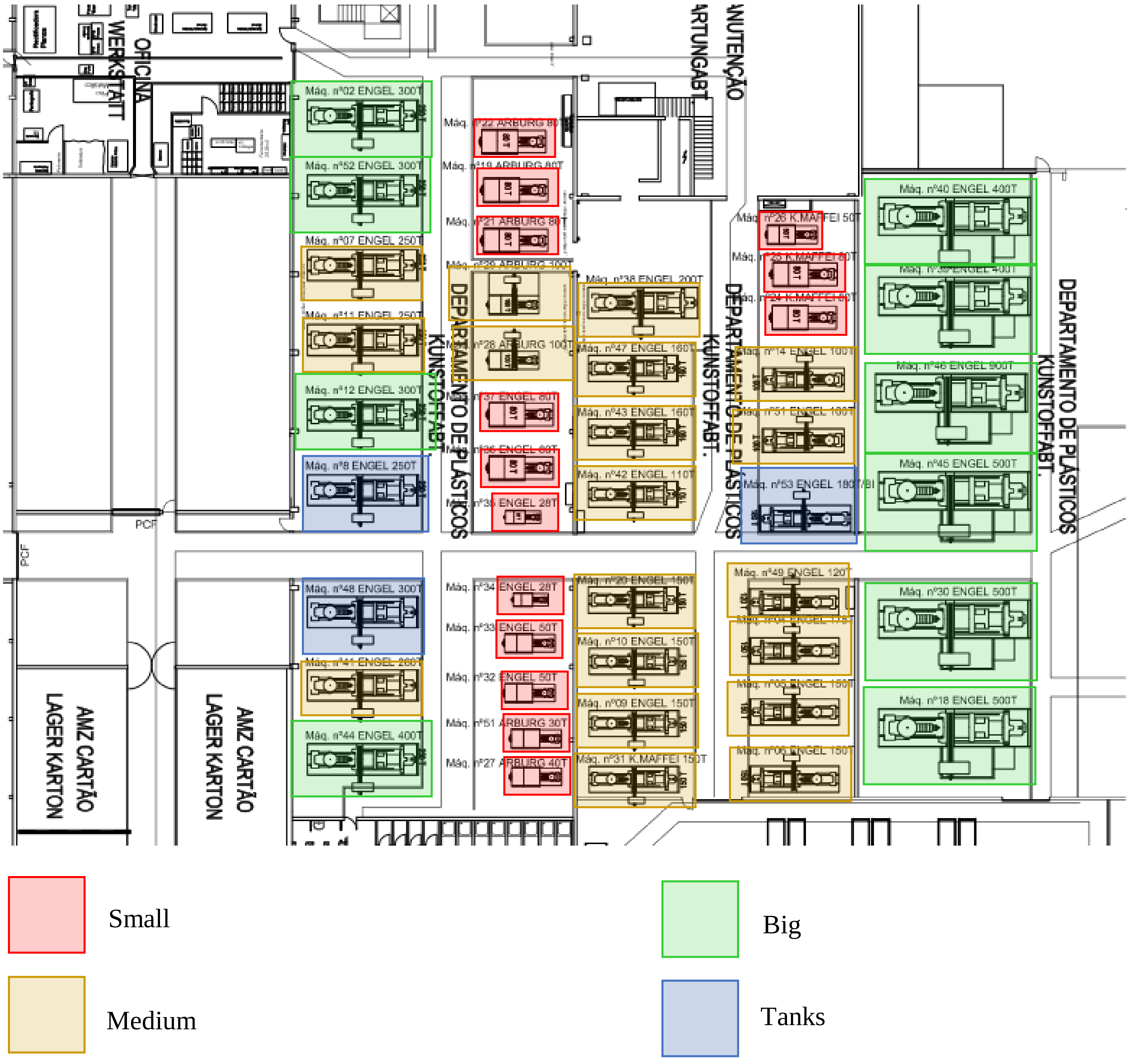


Figure 26 Initial machine layout with 46 machines

APPENDIX I: Machine Layout – Current Situation

Figure 27 Current machine layout with 51 machines

APPENDIX J: Daily Kaizen – Team Boards

Figure 28 Daily Kaizen – Raw Materials Warehousing and Mills Team

Figure 30 Daily Kaizen - Plastic Injection Processes Team

Figure 29 Daily Kaizen - Mold Maintenance Team

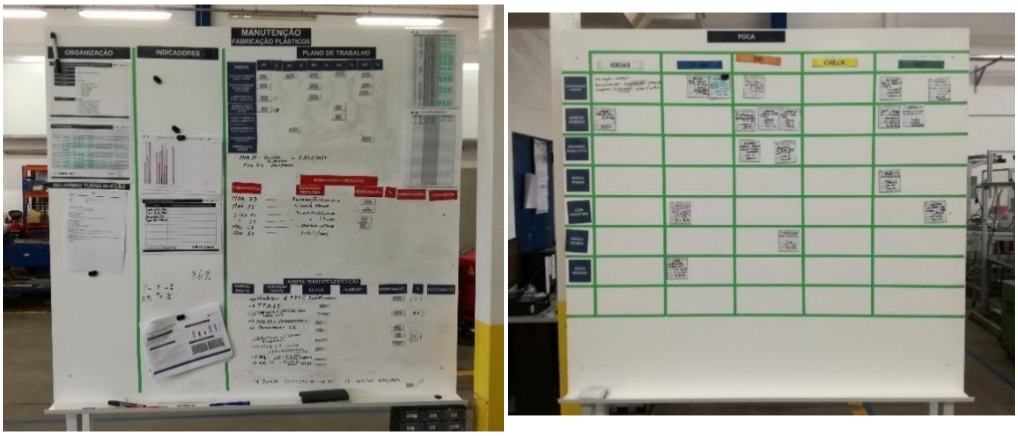


Figure 32 Daily Kaizen - Maintenance Team

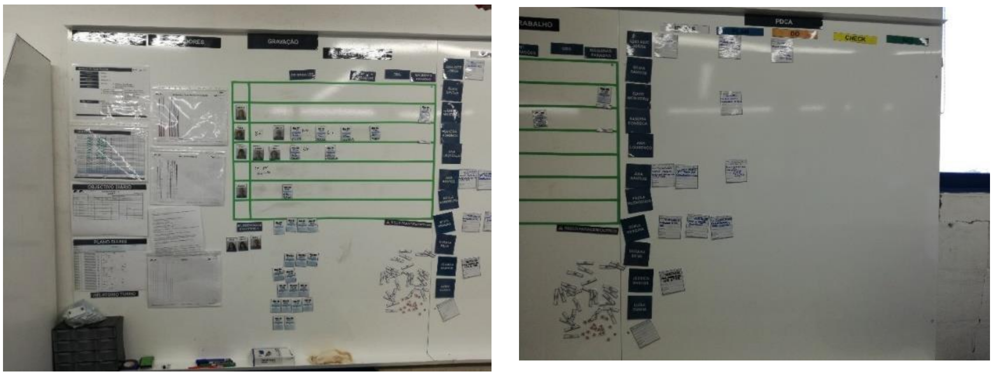


Figure 33 Daily Kaizen - Engraving Team

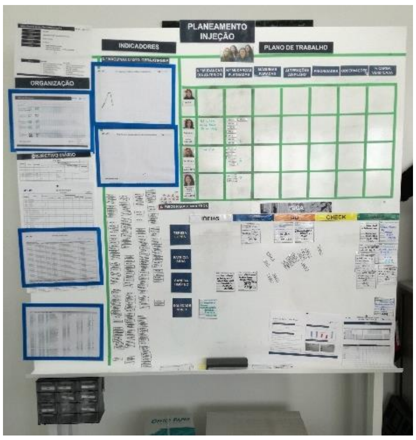


Figure 31 Daily Kaizen - Planning
Team

Figure 36 Daily Kaizen – DP daily meeting

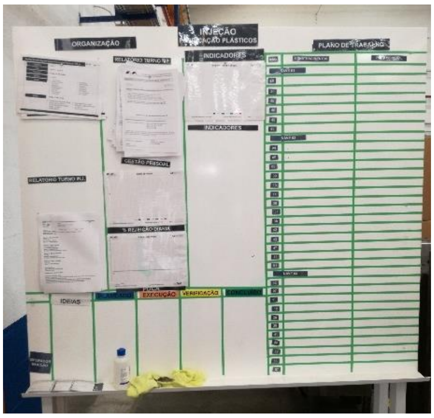


Figure 35 Daily Kaizen – Injection Shift Meeting

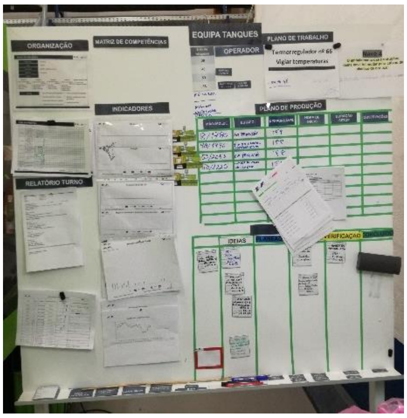


Figure 34 Daily Kaizen - Tanks Team

APPENDIX K: Border of Line – Initial Situation

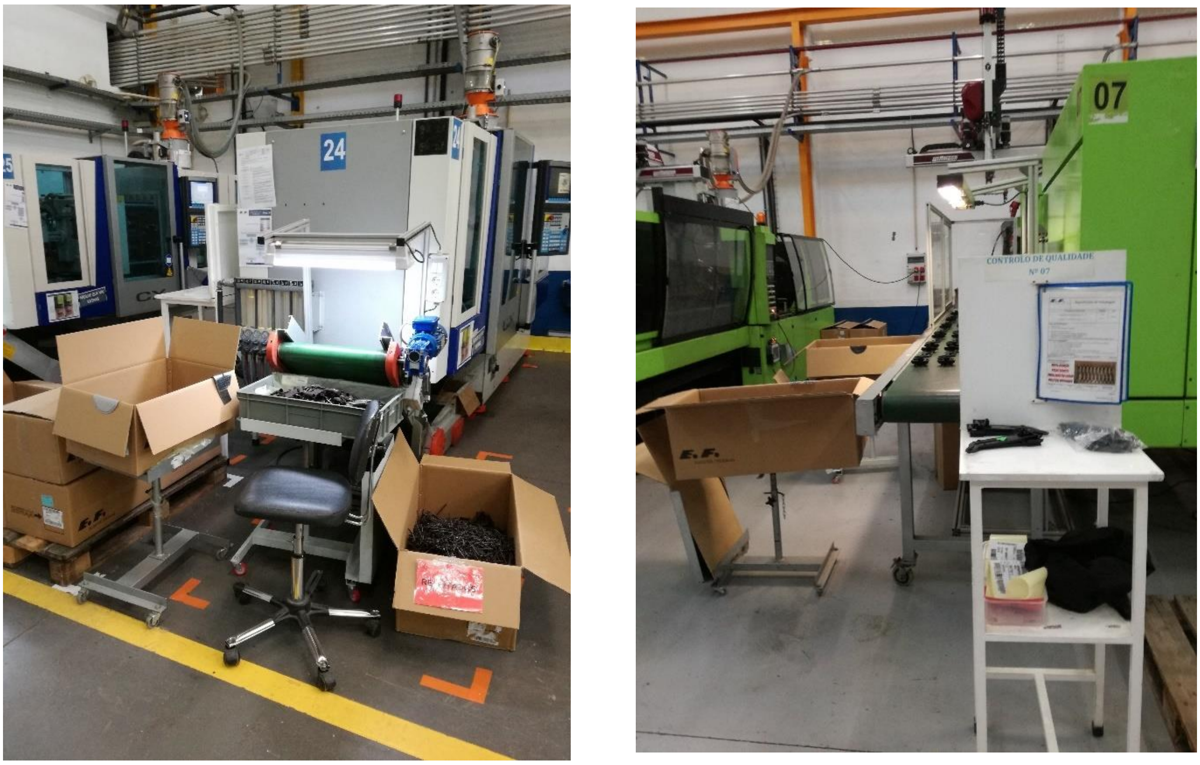


Figure 37 Initial Situation - Disorganized workplace, no standardized border of line, quality control far from operator

Appendix L: Border of line – New Design

Figure 38 New Border of line - All materials close to the operator, more ergonomic workplace, quality control stand in front of operator.

Appendix M: Visual Norm – Mold positioning before and after setup

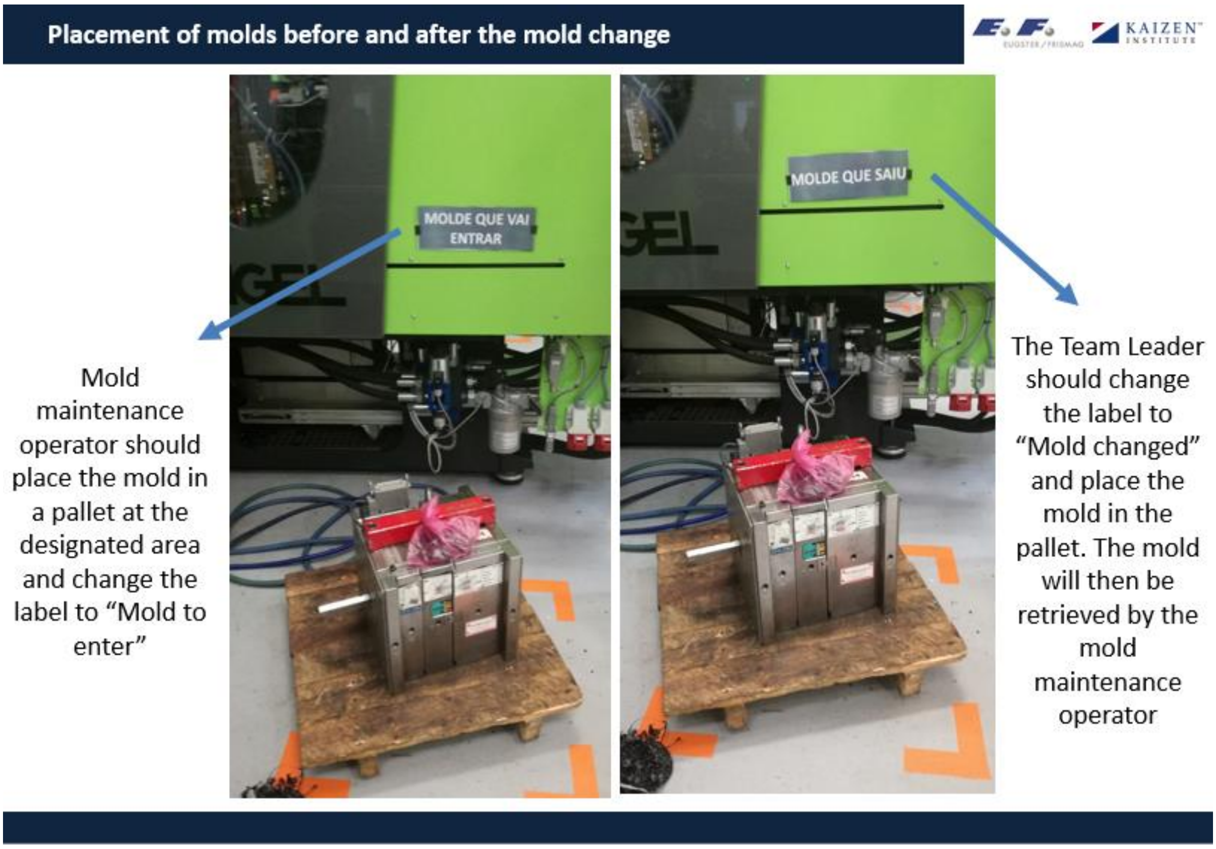
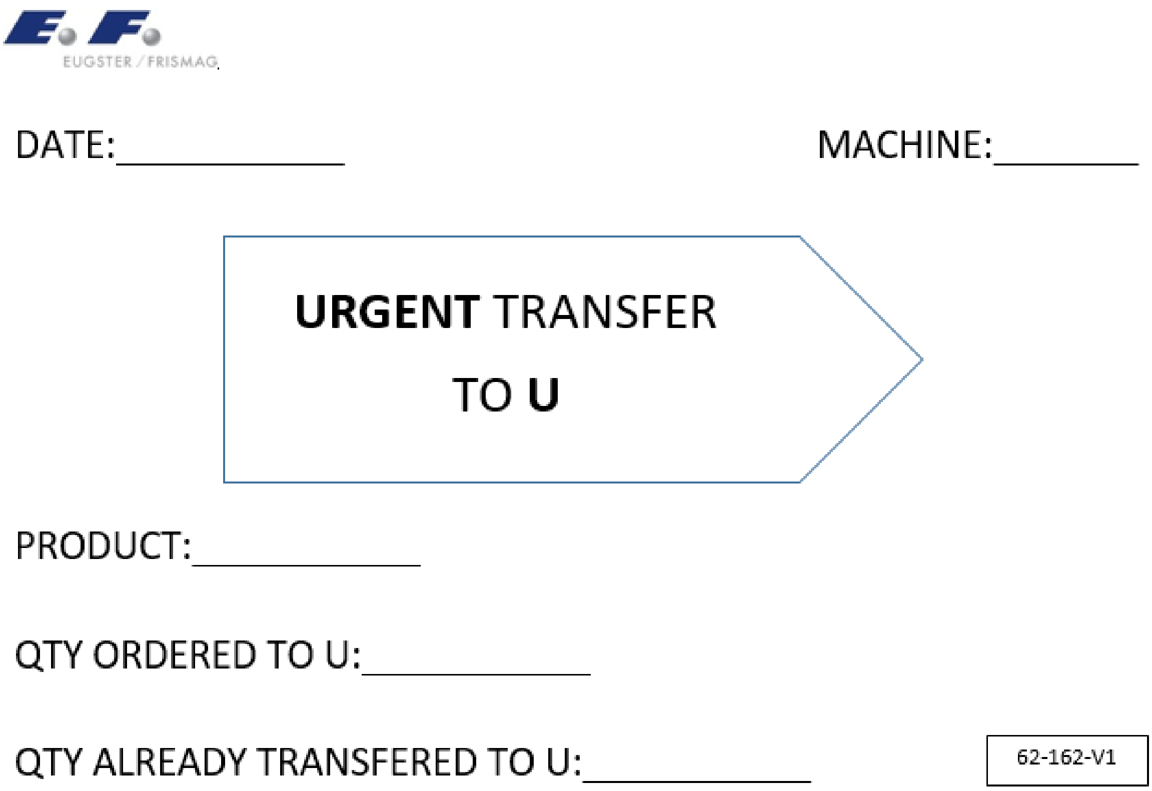


Figure 39 Visual Norm: mold placement before and after change

APPENDIX N: Visual Norm – Carton Car

Figure 40 Visual Norm: correct positioning of carton materials near operators

Appendix O: Visual Management – Mizusumashi urgencies update


EUGSTER / FRISMAG

DATE:____________ MACHINE:________

URGENT TRANSFER

TO **U**

PRODUCT:____________

QTY ORDERED TO U:____________

QTY ALREADY TRANSFERED TO U:____________

62-162-V1

Figure 41 Visual help: Mizusumashi urgencies update

Appendix P: Work Instruction for machine 32

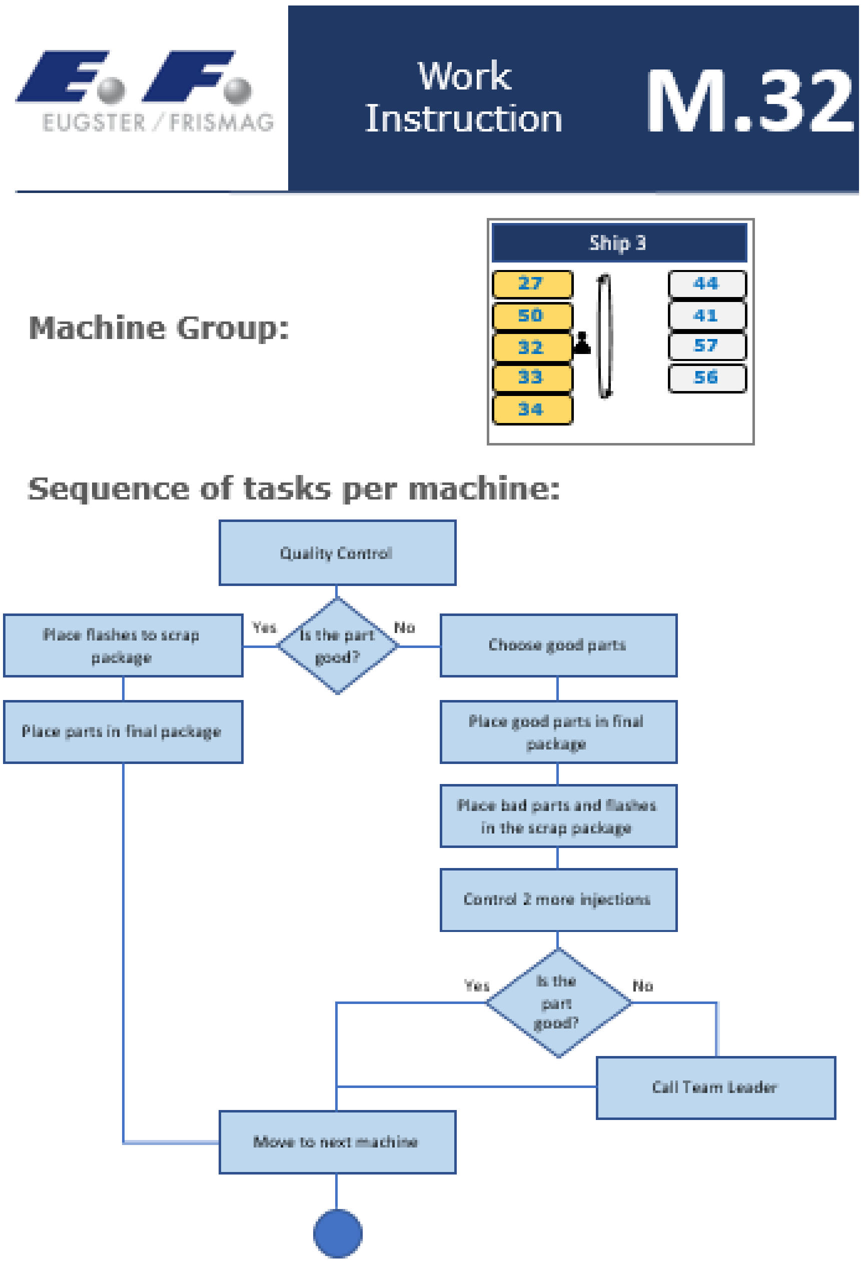


Figure 42 Work Instruction: Machine 32

Appendix Q: Work Instruction for cleaning the hopper

EUGSTER / FRISMAG

Work Instruction

Task: Hopper cleaning

Responsible: Operators

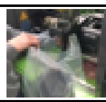
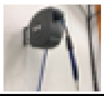
No	Taks	Duration	Foto
1	Place tube in hopper to take out the raw material out of it. Help Team Leader while material is coming out.	02:00	
2	Take pressurized air device	00:15	
3	Climb on top of the machine using the ladder	00:30	
4	Open upper-end of hopper and clean the filter	00:25	
5	Clean interior of upper-end of hopper	00:30	
6	Place filter at right place and close upper-end of hopper	00:15	
7	Open bottom-end of hopper	00:12	
8	Take out filter and clean it	00:25	
9	Cleand interior of bottom-end of hopper	00:30	
10	Place filter at right place and close bottom-end of hopper	00:20	
	Total:	05:22	

Figure 43 Work Instruction: cleaning hopper

Appendix R: Setup time evolution

Table 13 Setup time evolution: The setup time decreased right after week 9 when the SMED workshop occurred

	Type of Machine			
	Small	**Medium**	**Large**	**Tanks**
Average 2016	02:09:28	02:14:44	04:23:47	04:23:47
Week 5	02:35:35	02:31:13	02:34:40	02:55:34
Week 6	02:12:14	02:05:51	02:42:20	03:41:33
Week 7	02:35:40	03:18:10	02:12:31	05:05:15
Week 8	02:25:16	02:47:15	02:19:47	04:27:26
Week 9	01:49:21	02:12:43	04:21:59	06:06:17
Week 10	01:40:52	02:23:29	03:20:38	01:39:35
Week 11	02:03:15	02:02:48	04:10:39	
Week 12	01:55:55	02:17:58	02:47:43	06:11:48
Week 13	02:05:02	02:41:26	02:47:36	03:09:56
Week 14	02:01:31	02:54:15	02:03:24	03:25:58
Week 15	01:42:02	03:47:01	02:42:39	00:56:41
Week 16	01:27:16	02:07:52	02:56:31	03:36:35
Week 17	01:36:50	01:53:46	02:15:19	00:46:50
Week 18	01:35:56	02:03:47	04:49:40	04:00:23
Week 19	01:32:44	04:18:23	05:58:03	04:08:35
Week 20	01:32:17	03:23:41	05:30:27	03:08:05
Week 21	01:32:09	2:12:42	02:09:08	01:29:18

Appendix S: SMED – Initial Situation (with TL in charge of mold changing, before the SMED workshop)

Table 14 Mold Changing - Situation before SMED workshop

	Setup Operation		
Initial Situation		Duration:	
No	Description	Type of Task	Duration
1	Stop machine in the system	External	01:00
2	Prepare tools	External	00:30
3	Get mold	External	03:30
4	Prepare tools	External	01:30
5	Get mold folder	External	02:00
6	Place bridge next to machine	Internal	00:15
7	Stop machine	Internal	00:30
8	Turn off thermoregulators	Internal	01:15
9	Unload fuse	Internal	05:30
10	Unmount mold	Internal	00:50
11	Get new mold	External	02:10
12	Place mold into machine	Internal	00:45
13	Adjust cramps	Internal	02:00
14	Put away stacker	External	00:30
15	Mount mold	Internal	06:00
16	Adjust temperature	Internal	00:30
17	Open mold	Internal	00:15
18	Upload program	Internal	00:30
19	Turn on water, air and extraction	Internal	07:20
20	Turn thermoregulator on	Internal	00:25
21	Turn safety off	Internal	01:30
22	Get plastic bags and disconnect raw materials tube	External	04:30
23	End mounting and begin fine-tunning in system	Internal	01:45
24	Clean hopper	Internal	05:00
25	Clean mold	Internal	01:30
26	Clean hopper	Internal	07:10
27	Connect raw materials tube	Internal	04:30
28	Get cleaning material	External	02:30
29	Clean fuse	Internal	06:30
30	Begin fine-tunning	Internal	14:30
31	Put mold away	External	02:00
32	Quality approval	External	05:00
			92:40
			78:10

Appendix T: SMED - Standard Work

Table 15 SMED - Standard Work for TL

EUGSTER/FRISMAG	Setup Operation				KAIZEN INSTITUTE
Responsible	Team Leader		Objective internal time:	60 min	

No	Description	Type of Task	Responsible	Fase	Duration
1	Get mold folder (beginning of shift)	External	TL	Preparation	01:30
2	Get mold (beginning of shift)	External	OMM		03:30
3	Get cleaning material (beginning of shift)	External	TL		02:30
4	Prepare tools	External	TL		00:30
5	Place bridge next to machine	External	TL		02:00
6	Get plastic bags for plastic grains	External	TL		04:30
7	Disconnect raw material tube	External	RMM		
8	Start machine stoppage	External	TL		01:00
9	Stop machine	Internal	TL	Unmount	00:15
10	Stop thermoregulators	Internal	TL		00:30
11	Unload fuse	Internal	TL		01:15
12	Clean fuse	Internal	TL		06:30
13	Adjust temperatures	Internal	TL		00:30
14	Dismantle mold	Internal	TL		05:30
15	Take mold out of machine	Internal	TL		00:50
16	Adjust cramps	Internal	TL	Mount and fine-tune	02:00
17	Mount mold on machine	Internal	TL		06:00
18	Open mold	Internal	TL		00:15
19	Upload program	Internal	TL		00:30
20	Turn on water, air, and extraction cord	Internal	TL		07:20
21	Turn on thermoregulators	Internal	TL		00:25
22	Shut of safety	Internal	TL		01:30
23	Introduce end of mount and beginning of tuning	Internal	TL		01:45
24	Clean hopper	Internal	TL		12:10
25	Clean mold	Internal	TL		01:30
26	Engage raw material tube	Internal	RMM		04:30
27	Fine tune	Internal	TL		14:30
28	Finish fine-tune	External	TL	Clean	
28	Put away stacker	External	TL		00:30
29	Store mold	External	TL		02:00
30	Quality Approval	External	QC		05:00
					89:15
					67:45

Table 16 - Standard work for mold changing with TL and operator

EUGSTER / FRISMAG	Setup Operation			KAIZEN INSTITUTE
Responsible	Team Leader	Objective internal time:	45 minutes	
No	Team Leader	Operator	Type of task	Duration
1	Get mold folder (beginning of shift)		External	01:30
2	Get cleaning material (beginning of shift)	Chek on board what is the material the next mold will need and	External	02:30
3	Get plastic bags (beginning of shift)		External	04:30
4	Call RMM to retrieve tubes of all changes		External	00:30
5	Write on board what material each mold change needs (beginning of shift)		External	01:00
6	Pull hopper to the side		External	00:10
7	Prepare tools		External	00:30
8	Place bridge next to machine		External	02:00
9	Stop thermoregulators and program temperature of next mold		External	00:20
10	Start machine stoppage		External	01:00
11	Stop machine		Internal	00:15
12	Clean fuse		Internal	06:30
13	Adjust temperatures		Internal	00:30
14	Apply spray	Cleam Hopper	Internal	04:30
15	Close mold		Internal	
16	Close bar		Internal	
17	Take peg out		Internal	
18	Take cramps out from mobile side (2)		Internal	
19	Take hoses out		Internal	
20	Take mold folder out		Internal	
21	Open machine		Internal	
22	Take cramps out from fix side (2)	Call RMM to engage raw material t	Internal	
23	Tale mold out of machine		Internal	00:50
24	Center mold		Internal	06:30
25	Adjust cramps	Adjust cramps	Internal	
26	Place cramps on fix side (2)	Place cramps on fix side (2)	Internal	
27	Place peg		Internal	
28	Close machine		Internal	
29	Take mold transportation safety out		Internal	
30	Place cramps on mobile side (2)	Place cramps on mobile side (2)	Internal	
31	Open mold		Internal	00:15
32	Turn on water and air		Internal	07:20
33	Turn on thermoregulators		Internal	00:25
34	Upload program		Internal	00:30
35	Turn of safety		Internal	01:30
36	Introduce end of monting and begin fine-tuning		Internal	01:45
37	Clean mold		Internal	01:30
38	Fine tunning		Internal	14:30
39	End fine-tunning		External	01:00
40	Put away stacker		External	00:30
41	Put away mold		External	02:00
42	Approve component		External	05:00
				80:00
				46:50

Appendix U: OEE Indicator Evolution

Table 17 OEE monthly evolution per machine type

Month	Small Machines (28-80T)	Medium Machines (100-260T)	Large Machines (300-900T)
01/16	85%	86%	80%
02/16	82%	81%	73%
03/16	81%	77%	70%
04/16	82%	77%	76%
05/16	87%	82%	75%
06/16	86%	79%	75%
07/16	86%	81%	76%
08/16	82%	66%	80%
09/16	82%	81%	81%
10/16	81%	76%	70%
11/16	83%	81%	72%
12/16	82%	79%	66%
01/17	84%	81%	70%
02/17	84%	80%	79%
03/17	85%	82%	71%
04/17	86%	81%	67%
Average 2016	83%	79%	75%
Average 2017	85%	81%	72%

Appendix V: Batch Size per Production Run Evolution

Table 18 Average batch size monthly evolution per machine type

Month	Small Machines (28-80T)	Medium Machines (100-260T)	Large Machines (300-900T)	Total
01/16	29700	10420	5008	45128
02/16	25449	14212	6934	46595
03/16	25085	11754	5327	42166
04/16	22100	11691	6402	40193
05/16	21340	15157	6674	43171
06/16	25416	13495	5963	44874
07/16	22188	11880	6634	40702
08/16	32371	8875	5738	46984
09/16	19136	9011	7065	35212
10/16	19125	11247	6656	37028
11/16	20052	11005	7654	38711
12/16	19545	14005	7914	41464
01/17	18305	11659	8155	38119
02/17	15788	12389	8134	36311
03/17	13408	11399	7892	32699
04/17	13023	13282	8093	34398
Average 2016	22648,72727	11896	6497,416667	41042,14
Average 2017	15131	12182,25	8068,5	35381,75
Difference	-33,19%	2,41%	24,18%	-13,79%

Appendix X: Mold changes per Machine Type Evolution

Table 19 Average mold changes per day per machine tonnage

Month	Small Machines (28-80T)	Medium Machines (100-260T)	Large Machines (300-900T)	Total	Changes per Shift - Small Machines
01/16	5,2	5,9	2,7	13,8	2,6
02/16	5,6	4,4	2,1	12,1	2,8
03/16	5,7	4,9	2,9	13,5	2,9
04/16	6,1	5,5	2,3	13,9	3,1
05/16	5,9	5,2	2,3	13,4	3,0
06/16	6,0	5,5	2,4	13,9	3,0
07/16	6,2	5,1	1,6	12,9	3,1
08/16	3,5	3,3	2,7	9,5	1,8
09/16	6,4	6,7	1,9	15,0	3,2
10/16	5,8	6,3	1,7	13,8	2,9
11/16	5,4	6,9	2,3	14,6	2,7
12/16	5,5	4,3	2,5	12,3	2,8
01/17	6,7	6,0	2,0	14,7	2,2
02/17	7,9	6,1	2,5	16,5	2,6
03/17	8,2	6,0	2,7	16,9	2,7
04/17	8,3	5,6	2,4	16,3	2,8
Average 2016	5,6	5,3	2,3	13,2	2,8
Average 2017	7,8	5,9	2,4	16,1	2,6

Appendix Y: Mold Maintenance Operator Standard Work

Table 20 Work Instruction: Standard Work for the small machines mold maintenance operator

EUGSTER / FRISMAG	Work Instruction		Area	ENI
			No	EFP-IT-DP-025
	Small machines' mold maintenance operator standard work		Date	
			Edition	1
	Elaboration		Approval	GFP
	Revision		Distribution	DP

This work instruction has as objective to show the time the machine operator should dedicate in his shift to each on of his tasks and the ideal order to execute them

Before the beginning of the shift	**Duration**	**Morning**	**Afternoon**	**Night**
1. Shift passage	5 minutes	05:55	13:55	21:55
Throughout the shift				
2. Daily Kaizen meeting with team	5 minutes	06:00	14:00	22:00
3. Place molds next to machines	30 minutes	06:05	14:05	22:05
4. Clean molds	5 hours	Throughout the shift	Throughout the shift	Throughout the shift
5. Lubricate molds	40 minutes			
6. Cover for breaks and put away changed molds	1 hour			
7. Small machine repairs, if necessary				
8. Break	30 minutes			
9. 5s workshop	10 minutes	13:50	21:50	05:50

Appendix W: Team Leader Standard Work

Table 21 Work Instruction: Standard Work for the small machines Team Leader

<table>
<tr><td rowspan="4">EUGSTER / FRISMAG</td><td colspan="2" rowspan="2">Work Instruction</td><td>Area</td><td>ENI</td></tr>
<tr><td>No</td><td>EFP-IT-DP-025</td></tr>
<tr><td colspan="2" rowspan="2">Small Machines' team leader Standard Work</td><td>Date</td><td></td></tr>
<tr><td>Edition</td><td>1</td></tr>
<tr><td></td><td>Elaboration</td><td></td><td>Approval</td><td>GFP</td></tr>
<tr><td></td><td>Revision</td><td></td><td>Distribution</td><td>DP</td></tr>
<tr><td colspan="5">This work instruction has as objective to show the time the machine operator should dedicate in his shift to each on of his tasks and the ideal order to execute them</td></tr>
<tr><td colspan="2">Before the beginning of the shift</td><td>Duration</td><td>Morning</td><td>Afternoon</td><td>Night</td></tr>
<tr><td colspan="2">1. Shift passage</td><td>5 minutes</td><td>05:55</td><td>13:55</td><td>21:55</td></tr>
<tr><td colspan="6">Throughout the shift</td></tr>
<tr><td colspan="2">2. Daily Kaizen meeting with team</td><td>5 minutes</td><td>06:00</td><td>14:00</td><td>22:00</td></tr>
<tr><td colspan="2">3. Evaluation of planning production/ plan changes</td><td>5 minutes</td><td>06:05</td><td>14:05</td><td>22:05</td></tr>
<tr><td colspan="2">4. Prepare machines setup:
- Get mould folders
- Get cleaning materials and plastic bags
- Call RMM to inform about changes
- Inform the operators about the material they need during the shift</td><td>10 minutes</td><td>06:15</td><td>14:15</td><td>22:15</td></tr>
<tr><td colspan="2">5. Machines Setup
-Unmount mold
-Mount mold
-Clean mold
-Fine-tune
-Quality control</td><td>4 hours e 15 minutes</td><td rowspan="5">Throughout the shift</td><td rowspan="5">Throughout the shift</td><td rowspan="5">Throughout the shift</td></tr>
<tr><td colspan="2">6. Break</td><td>30 minutes</td></tr>
<tr><td colspan="2">7. Quality control of machines in production (5 minutes per machine, 16 machines)</td><td>1 hour e 20 minutes</td></tr>
<tr><td colspan="2">8. Training / Team managemet</td><td>30 minutes</td></tr>
<tr><td colspan="2">9. Resolution of problems, if necessary:
-Retune of machines
- Raw Materials changes
- Obstructued cirtuits</td><td>1 hour</td></tr>
<tr><td colspan="2">10. Preparation of information to pass to the next shift and update indicators</td><td>5 minutes</td><td>13:50</td><td>21:50</td><td>05:50</td></tr>
</table>

Appendix Z – Small Machines Operator Standard Work

Table 22 Work Instruction: Standard Work for small machines operators

EUGSTER / FRISMAG				
	Work Instruction		**Area**	**ENI**
			No	EFP-IT-DP-025
	Small Machines' operator Standard Work		**Date**	
			Edition	**1**
	Elaboration		**Approval**	**GFP**
	Revision		**Distribution**	**DP**

This work instruction has as objective to show the time the machine operator should dedicate in his shift to each on of his tasks and the ideal order to execute them

<table>
<tr><th>During the shift</th><th>Duration</th><th>Morning</th><th>Afternoon</th><th>Night</th></tr>
<tr><td>1. Daily Kaizen meeting with team</td><td>5 min</td><td>06:00</td><td>14:00</td><td>22:00</td></tr>
<tr><td>2. Machines:
- Start machines after stoppage
- Weigh components
- Update production in system
- Print production labels
- Perform quality control on components
- Pack components
- Grind components when necessary</td><td>6 hours and 45 min</td><td rowspan="3">Throughout the shift</td><td rowspan="3">Throughout the shift</td><td rowspan="3">Throughout the shift</td></tr>
<tr><td>3. Support TL in mold changing
- Prepare setup, if necessary
- Clean hopper
- Place cramps</td><td>30 min</td></tr>
<tr><td>4. Break</td><td>30 min</td></tr>
<tr><td>5. 5s to machines</td><td>10 min</td><td>13:50</td><td>21:50</td><td>05:50</td></tr>
</table>

Appendix AA - Mizusumashi Workload Analysis

Table 23 Mizusumashi: time spent per task using a hand pallet truck (min)

Hand pallet truck			
Task List	**Task time (min)**	**Task Frequency/shift**	**Time spent/shift**
Transfer Pallets to warehouse	5	32	160
Replenish pallets to each ship	15	2	30
Replenish large carton boxes and large separators	60	2	120
Replenish small carton boxes and small separators	15	2	30
Replenish Braun boxes, blisters and sponges	15	2	30
Collect boxes with rejected pieces and transfer them to raw materials warehouse	25	2	50
Scan boxes	0,5	186	93
Total			513

Table 24 Mizusumashi: time spent per task using a stacker (min)

Stacker			
Task List	**Task time (min)**	**Task Frequency/shift**	**Time spent/shift**
Transfer Pallets to warehouse	4	32	128
Replenish pallets to each ship	10	2	20
Replenish large carton boxes and large separators	45	2	90
Replenish small carton boxes and small separators	10	2	20
Replenish Braun boxes, blisters and sponges	10	2	20
Collect boxes with rejected pieces and transfer them to raw materials warehouse	20	2	40
Scan boxes	0,5	186	93
Total			411

APPENDIX AB – Mizusumashi Shadowing Template

Shift: A
Operator: XXX
Date: 03/03/2017

Time Writing

Beggining	End	Duration	Added Value or Muda?	Added Value (accumulated)	MUDA (accumulated)	Description	Opportunities
06:00	06:05	00:05	VA	00:05	0	Shift change	
06:15	06:33	00:18	VA	00:23	0	Distribute large carton boxes	
06:33	06:45	00:12	MUDA	00:23	00:12	Problem: Had to retrieve carton from racks	
06:45	06:46	00:01	MUDA	00:23	00:13	Check which moulds are going to change next	Should be clear on the team board, so he does not have to go to the ERP system
06:46	06:52	00:06	VA	00:29	00:13	Distribute sponges	
06:52	06:58	00:06	VA	00:35	00:13	Distribute large separators	
06:58	07:03	00:05	VA	00:40	00:13	Retrieve pallets	
07:03	07:06	00:03	VA	00:43	00:13	Replenishment of blue separators (tanks)	
07:06	07:08	00:02	VA	00:45	00:13	Recharge printer	
07:08	07:10	00:02	VA	00:47	00:13	Replinish pallets to ship 2	Need for 5s
07:10	07:12	00:02	VA	00:49	00:13	Transport pallets to quality area	
07:12	07:17	00:05	Va	00:54	00:13	Retrieve pallet	
07:17	07:37	00:20	MUDA	00:54	00:33	Break	
08:10	08:35	00:25	MUDA	00:54	00:58	Problem: stock error	The mizu should be able to solve these problems by himself, without the need to contact the planning team
10:00	10:13	00:13	MUDA	00:54	01:11	Problem: cannot print label for rejected parts because mould was already changed	The operator should be the one printing and placing these labels
12:50	13:20	00:30	VA	01:24	01:11	Retrieve rejected parts (25 boxes)	
13:20	13:35	00:15	VA	01:39	01:11	Store rejected parts (25 boxes)	
13:35	13:47	00:12	MUDA	01:39	01:23	Scan cartons with goods (40 boxes)	he operator should do this operatio
		TOTAL AV	54%	TOTAL MUDA	46%		

Layout - Spaghetti Diagram

Definition of Added Value of the Process:

Retrieve and replenish all materials from border of line, so operators do not need to move from their workplace

Figure 44 Time Writing – The tool used to find the mizu's difficulties and create a better working standard

APPENDIX AC – Team Leader Shadowing Template

Day	Shift
25/02/2017	A

	Team Development			Team Work Planning	Fire-fighting								Personal Organization				Meetings		Other Tasks	
	Team Member training	Audit/verify work standards	Give team member feedback	Team Work Planning	Help team member in problem solving	Work replanning	Correct mistakes/wrong information	Solve machine stoppage	Solve quality problems	Non-planned activity	Help other departments	Ask other departments for help	Email management	Organize/clean workplace	Fill in repoerts/indicators	Plan activities	Project meeting	Non-planned meeting		Notes
06:00																				
06:10				■																TL was on vacations:
06:20									■											get on track with what happend in his absence
06:30																				
06:40										■										
06:50				■	■															Fix assembly test on machine 32
07:00				■																"Go around the plant to check what people are doing"
07:10													■							
07:20													■							
07:30													■							
07:40													■							
07:50				■																
08:00					■				■											
08:10								■												Clean Machine
08:20								■												
08:30								■												Problem at assembly machine next to machine 40
08:40						■														
08:50								■				■								Ask for help to maintenance team
09:00								■				■								
09:10	■							■												Help team member with assembly process
09:20	■							■												and norm creation
09:30	■				■															
09:40				■								■								Assign one person to take out pallets from ship 4
09:50	■									■		■								Problems with raw material
10:00										■										
10:10																			■	
10:20		■						■												
10:30								■												
10:40	■	■																		Traing team member with assembly process
10:50	■	■																		
11:00																				Break
11:10																				Break
11:20																				Break
11:30																				
11:40																				
11:50																				
12:00																				
12:10								■												Quality problem
12:20								■												
12:30								■												
12:40								■												
12:50		■																		Help operator organize workspace
13:00	■	■																		
13:10								■							■					
13:20								■												
13:30								■												
13:40								■												
13:50															■					
14:00															■					

Figure 45 Time Writing - Following TLs is key to understand what they do during their working day

APPENDIX AD: Machine Layout – Future Situation of ship 4

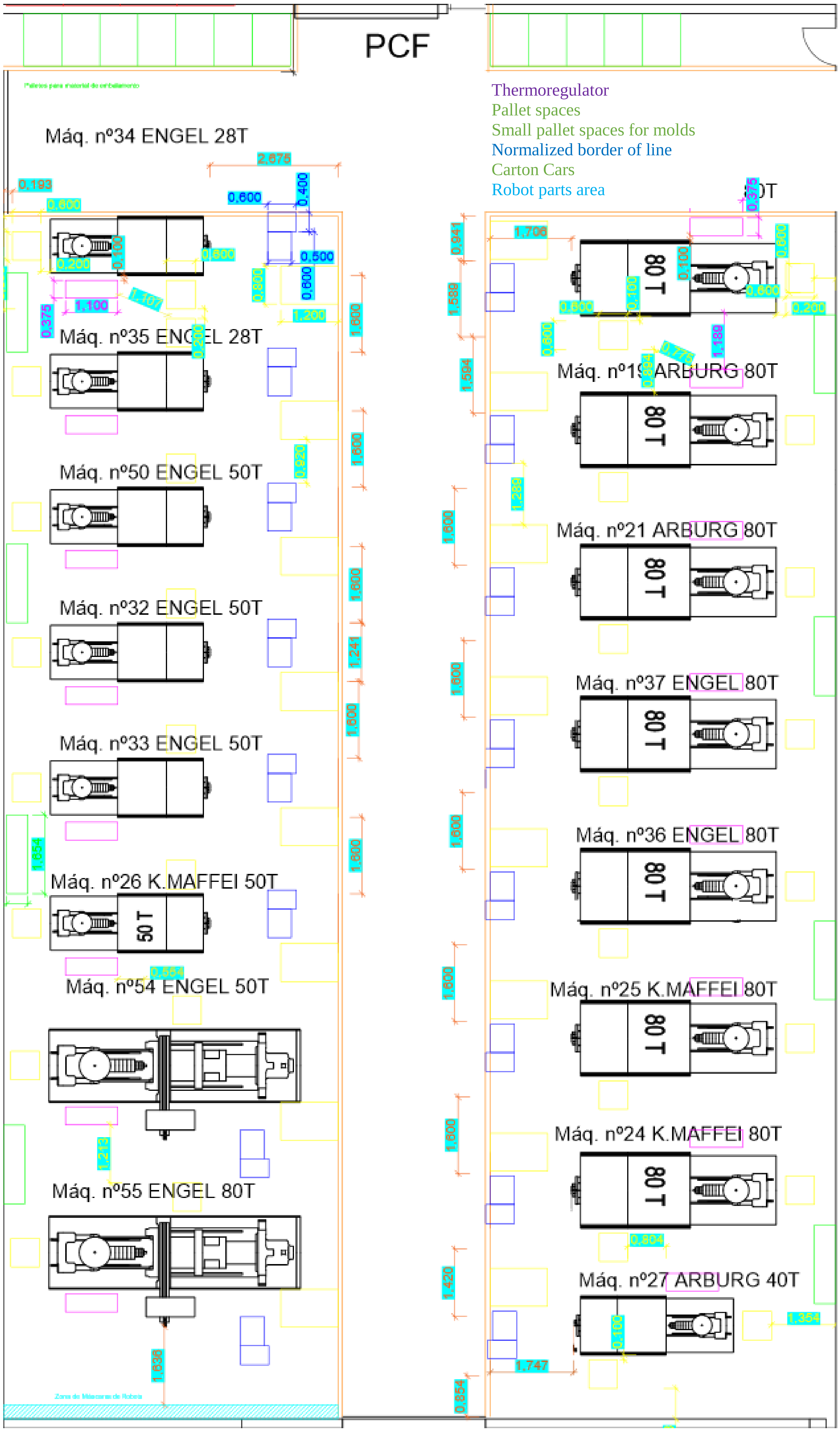


Figure 46 Future layout of ship 4, dedicated to small machines