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Implementation of TPM and 6S Lean in Sonafi

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Dissertation presented to ISEP – School of Engineering to fulfil the requirements necessary to obtain a master's degree in mechanical engineering, carried out under the guidance of Prof. Sandra Cristina de Faria Ramos and Prof. Francisco José Gomes da Silva

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“There is in nowadays an important company Sonafi on going to implement TPM and 6S Lean under maintenance department, therefore, I have immediately volunteered myself to help on this greater target achievement by taking this subject under my responsibility as soon I knew about it.”

SIVASANGARANE NADARADJANE ANANDANE, 2018

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KEYWORDS

TPM; Autonomous Maintenance; Curative Maintenance; Automotive Industry; OEE; Lean 6S; IATF 16949:2016; Cost reduction; Improvement in efficiency; Improvement in performance; Improvement in quality and safety; Total Quality Management; ISO 9001:2015; Quality Management System.

ABSTRACT

In today's industrial scenario huge losses/wastage occur in the manufacturing shop floor. This waste is due to operators, maintenance personal, process, tooling problems and non-availability of components in time etc. Other forms of waste includes idle machines, idle manpower, break down machine, rejected parts etc are all examples of waste. The quality related waste are of significant importance as they matter the company in terms of time, material and the hard earned reputation of the company. There are also other invisible wastes like operating the machines below the rated speed, startup loss, break down of the machines and bottle necks in process. Zero oriented concepts such as zero tolerance for waste, defects, break down and zero accidents are becoming a pre-requisite in the manufacturing and assembly industry. A fundamental component of world-class manufacturing is that of the Total Productive Maintenance (TPM), which has been recognized as one of the significant operation strategy to regain the production losses due to equipment inefficiency. TPM is the methodology that aims to increase both availability of the existing equipment hence reducing the need for the further capital investment.

The automotive sector constitutes one of the most demanding activities in the global market, since it requires a constant increase in productivity, both in the automobile industry as well as in the companies whose manufacture its components. This sector is currently set within an economic framework where there is a relentless search for costs reduction and an increase in productivity with minimal investment. In order to meet these requirements, companies have sought to optimise their products and processes to ensure higher profits.

The main aim is to develop a framework with the capability of assessing the impact of implementing TPM in a company which supplies die-casting products to the automotive sector. The major action was taken in the autonomous and curative maintenance. Due to the undertaken improvements, there was a 2% increase in OEE (Overall Equipment Effectiveness) on line AA3. Along with TPM, 6S Lean is also implemented that is one of the main points of the new standard for automotive industry IATF 16949:2016.

PALAVRAS CHAVE

TPM; Manutenção autónoma; Manutenção Curativa; Indústria automobilística; OEE; Lean 6S; IATF 16949: 2016; Redução de custos; Melhoria na eficiência; Melhoria no desempenho; Melhoria na qualidade e segurança; Gestão de Qualidade Total; ISO 9001: 2015; Sistema de Gestão da Qualidade

RESUMO

Actualmente, qualquer perda/desperdício afeta a competetividade das organizações. Este desperdício deve-se, muitas vezes, à falta de manutenção e consequente indisponibilidade de equipamentos. Outras formas de desperdício são o excesso de produção, o processamento inapropriado, os defeitos, roturas de stocks, etc. Todos os tipos de desperdício são relevantes, contudo os relacionados com a qualidade são de importância significativa, uma vez que têm influência na reputação da empresa. Tolerância zero para o desperdício e para o número de acidentes tem-se revelado um pré-requisito na indústria de produção e montagem. Um aliado no cumprimento deste pré-requisito é a Manutenção Produtiva Total (TPM). A TPM é uma metodologia que visa aumentar a disponibilidade do equipamento existente, reduzindo assim a necessidade de mais investimento de capital.

O setor automóvel constitui uma das atividades mais exigentes do mercado global, pois exige um aumento constante de produtividade, tanto na indústria automobilística como nas empresas que fabricam os seus componentes. Atualmente, este setor está inserido numa estrutura económica que procura incessantemente a redução de custos e um aumento na produtividade com um investimento mínimo. Para atender a esses requisitos, as empresas têm procurado otimizar os seus produtos e processos para garantir maiores lucros.

Neste documento, apresentam-se os resultados de estudo desenvolvido com o objetivo de aprimorar os procedimentos no setor de manutenção de uma empresa que fornece produtos de fundição para o setor automóvel. O principal objetivo foi aumentar a disponibilidade de máquinas e equipamentos através da implementação da metodologia TPM.

As alterações introduzidas na linha AA3 resultaram num aumento de 2% no valor do indicador de desempenho Overall Equipment Effectiveness (OEE).

Juntamente com a metodologia TPM foi impementada a metodologia 6S Lean, vista como uma estratégia abrangente, poderosa, eficaz e adequada para a solução de todos os tipos de problemas relacionados com a melhoria de processos e produtos.

LIST OF SYMBOLS AND ABBREVIATIONS

List of abbreviations

A	Availability
CSR	Customer Specific Requirements
FMEA	Failure Mode and Effects Analysis
IATF	International Automotive Task Force
JIPE	Japanese Institute of Plant Engineers
ME	Maintenance Equipment
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
OEE	Overall Equipment Effectiveness
OT	Open Text
PE	Performance Efficiency
PPM	Planned Preventive Maintenance
Q	Quality Rate
RCFA	Root Cause Failure Analysis
RCM	Reliability Centered Maintenance
RE	Rate Efficiency
SGA	Small Group Activity
TPM	Total Productive Maintenance
TQM	Total Quality Management
WBL	Work Based Learning

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INTRODUCTION

INTRODUCTION

This chapter presents the introduction in order to understand the problem. It covers the background and issues related to the research project. It also presents the objectives and purpose. Finally, the research methodology and the structure of the thesis are presented.

1.1 BACKGROUND

Due to the market high demand, the industry has been pressed to develop and adopt new production technologies and techniques, as well as management procedures, without chances for failures or waste. Faced with these scenarios, companies must continuously enhance their activities in order to survive in this competitive environment. This demand invariably affects the maintenance sector which, together with production, must carry out their activities in such a way that these do not interfere with the course of the productive process. To this end, a revolutionary concept of Total Productive Maintenance (TPM) has been adopted by many industries across the world. Zero oriented concepts like zero inventories, zero lead time, zero defects, and zero tolerance for waste, breakdown and zero accidents are becoming the pre-requisite for the production plant which can be achieved by implementing TPM [2].

TPM was first developed in Japan, it is team-based preventive and productive maintenance and involves every level, from top executive to the floor operator. TPM has been proven to be successful in helping to increase productivity and Overall Equipment Effectiveness(OEE). The underlying concept is, if the plant machinery is not maintained there will see a sharp decline in machine breakdowns, safety and quality problems [1].

The work described in this thesis was developed at a company in the sector of components for the automotive industry, which is located in Porto, Portugal. TPM methodology was implemented and associated with other Lean philosophy tools (6S and Visual Management) with the purpose of improving actions in the maintenance sector of a production line, which would then reduce the stoppage rates resulting from machine breakdowns.

1.2 OBJECTIVES

The aim of this thesis is to implement TPM methodology in the company SONAFI to improve both productivity and quality along with the increased employee morale and job satisfaction. So in order to accomplish the above-stated aim, below are the main set objectives:

1. To understand the TPM and Lean tools.
2. Investigating the existing operational activities in order to understand their manufacturing issues.
3. Identifying the key points for implementing TPM in Sonafi plant and establishing the TPM working system and target.
4. Identifying factors that determine the assessment of TPM.
5. To recommends appropriate lean techniques and processes in order to simplify and standardize the work processes.
6. Identifying the TPM techniques that provide improvement opportunities throughout enterprise operations.
7. Selecting TPM methods requires strong and active support from management with clear organizational goals.
8. TPM tools analyze the organization to create a corporate environment able to respond positively to the changing technological advances, equipment sophistication and management innovation.
9. Lean techniques aid to maximize customer value while minimizing waste.
10. Lean tools guide us how a company should conduct functions, it takes a long-term perspective and perseverance.

1.3 RESEARCH METHODOLOGY

The work began with an informative research as the thesis involved a deep understanding of the TPM and LEAN tools. Followed by the collection of key information, either through direct observation of the processes, through company records or through the interviews conducted with maintenance personnel, machine operators and other employees in the production department.

The TPM implementation stage was followed. In this stage, several activities are carried which are called pillars in the development of TPM activity. A qualitative approach is used to assess the maintenance systems and to calculate OEE.

1.4 THESIS STRUCTURE

This document is divided into six sections. Section 1 consists of the introduction and Section 2 presents a review of literature pertaining to the subject of maintenance optimization tools. Section 3 deals with the analysis of the company with the methodology developed to carry out the work and also describes the course of all the practical work involved and undertaken at the company being studied. This section also presents improvement proposals for identified problems, as well as the results obtained from their implementation. Section 4 deals with the conclusions reached through this research work and Section 5 deals with reference and another source of information. Finally, Section 6 deals with annexes. Figure 1 represents the thesis content flowchart of the implementation of TPM and 6S in Sonafi.

1.5 DECLARATION

We all know that Total Productive Maintenance (TPM) has standard 8 Pillars has designed by Nakajima's 1988 like Focused Improvement, Autonomous Maintenance, Preventive Maintenance, Training and Education, Initial Flow Control, Quality Maintenance, TPM in Administration and Safety&Health and Environment but this TPM is designed as per the Sonafi ME demand and expectation. Since Sonafi has a separate department for Quality, Safety and Human Resources they look after the respective fields. Quality Department took care of Quality aspects of Maintenance. Safety Department looks after Safety, Health and Environment aspects of Maintenace. Human Resource Department took care of Education and Training. In Sonafi we designed this TPM which has 7 Pillars like Maintenance Preventive (Predictive& Systematic), Curative Maintenance, Continous Improvements, Qualification of Human Resources, Support System, Autonomous Maintenance and Supplier Maintenance. Ultimate motive of this TPM design to increase the OEE (Overall Equipment Effectiveness) & increase the time of MTBF (Mean Time Between Failure) and decrease the time of MTTR (Mean time to Repair).

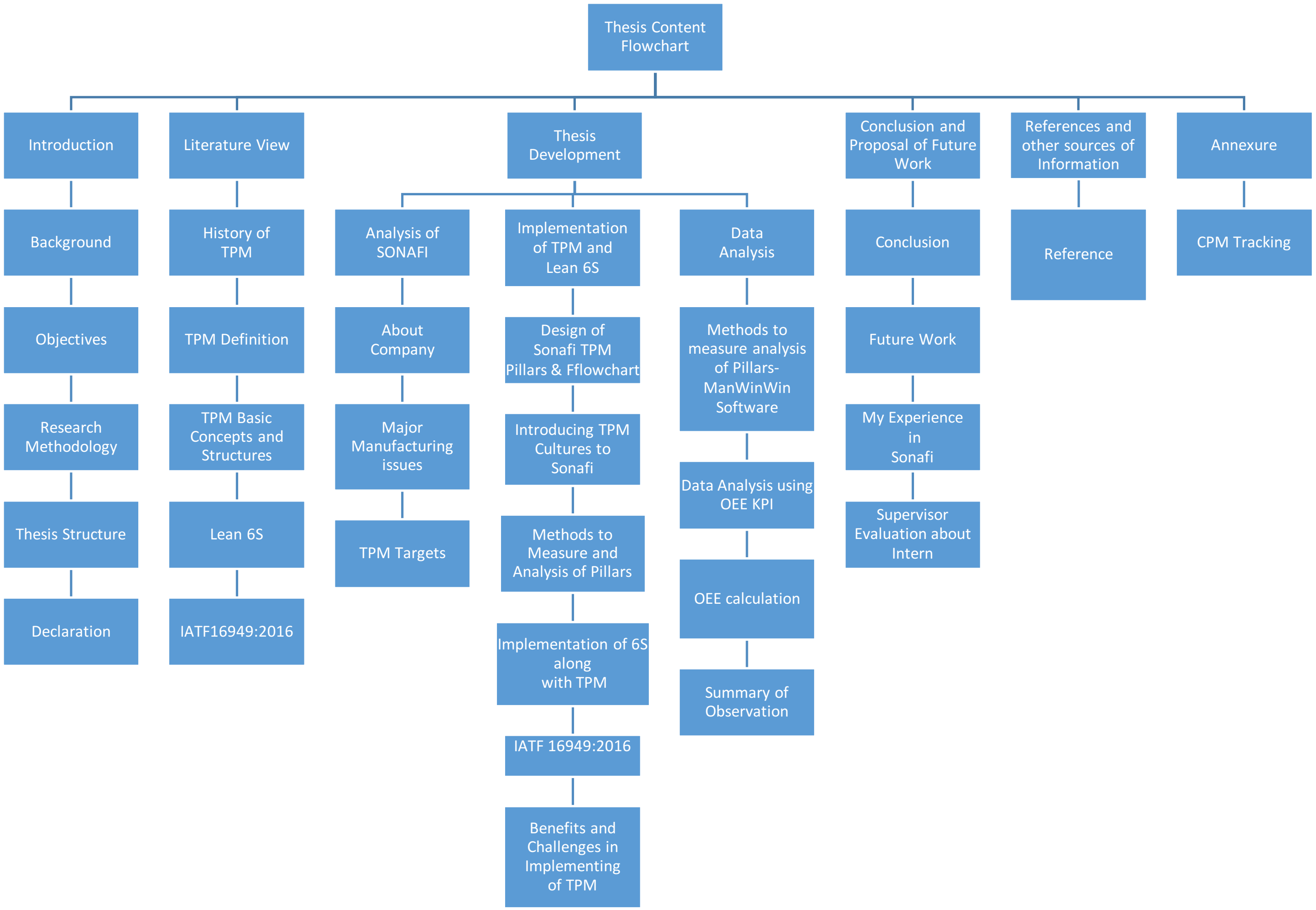


Figure 1 Thesis Structure.

BIBLIOGRAPHIC WORK

2 BIBLIOGRAPHIC WORK

2.1 BRIEF HISTORY OF TPM

The earliest roots of TPM trace back to the concept of Productive Maintenance (PM) that originated in the United States in the late 1940's and early 1950's. American Productive Maintenance was characterized by the development of scheduled Preventive Maintenance techniques to improve the reliability and longevity of manufacturing production equipment [5].TPM is an innovative Japanese concept. The origin of TPM can be traced back to 1951 when preventive maintenance was introduced in Japan. However, the concept of preventive maintenance was taken from the USA.

Nippon Denso was the first company to introduce plant wide preventive maintenance in 1960. Preventive maintenance is the concept wherein, operators produced goods using machines and the maintenance group was dedicated with work of maintaining those machines, however with the automation of Nippon Denso, maintenance became a problem, as more maintenance personnel were required. So, the management decided that the operators would carry out the routine maintenance of equipment. (This is Autonomous maintenance, one of the features of TPM). Maintenance group took up only essential maintenance works. Thus Nippon Denso, which already followed preventive maintenance, also added Autonomous maintenance done by production operators. The maintenance crew went in the equipment modification for improving reliability. The modifications were made or incorporated in new equipment. This lead to maintenance prevention. Thus, preventive maintenance along with Maintenance prevention and Maintainability Improvement gave birth to Productive maintenance. The aim of productive maintenance was to maximize plant and equipment effectiveness.

By then Nippon Denso had made quality circles, involving the employee's participation. Thus, all employees took part in implementing productive maintenance. Based on these developments Nippon Denso was awarded the distinguished plant prize for developing and implementing TPM, by the Japanese Institute of Plant Engineers (JIPE). Thus, Nippon Denso of the Toyota group became the first company to obtain the TPM certification [4].

The overview of the early milestones as TPM developed in Japan with emerging concepts, supporting theories, significant historical events in the different eras are represented in Table 1.

Table 1 TPM developed in Japan[5]

Era	1950's	1960's	1970's
Emerging Concepts	Preventive Maintenance- Establishing scheduled maintenance functions	Productive Maintenance(PM) – Recognizing the importance of equipment reliability, maintenance and ergonomic efficiency in plant design	Total Productive Maintenance (TPM) – Achieving PM efficiency through a comprehensive system based on respect for individuals and total employee participation
Supporting Theories	• Preventive Maintenance (PM) 1951 • Productive Maintenance (PM) 1954 • Maintainability Improvement (MI) 1957	• Maintenance Prevention (MP) 1960 • Reliability Engineering 1962 • Maintainability Engineering 1962 • Engineering Economics	Behavioral Science Management by Innovation and Creation (MIC) Performance Analysis and Control (PAC) Systems Engineering Ecology Terotechnology Maintenance Logistics
Significant Historical Events	1951 – Toa Nenryo Kogyo 1st Japanese company to adopt PM 1953 – 20 Japanese companies form a PM the research group which later became JIPM 1958 – American George Smith visits Japan to promote PM envoy	1960 – Japan hosts the first international maintenance convention 1962 – Japan Productivity Association sends an envoy to the US to study equipment engineering 1963 – Japan attends the International Convention on Equipment Maintenance in London 1964 – the first PM prize is awarded to Nippondenso in Japan 1969 – Japan Institute of Plant Engineers (JIPE) established, later to become Japan Institute of Plant Maintenance (JIPM)	1970 – the annual International Convention on Equipment Maintenance held in Japan 1973-the United Nations Industrial Development Organization sponsors a Maintenance Repair Symposium in Japan

2.1.1 Similarities and difference between TQM And TPM

The TPM program closely resembles the popular Total Quality Management (TQM) program (Table 2). Many of the tools such as employee empowerment, benchmarking, documentation (and others) used in TQM are used to implement and optimize TPM. Following are the similarities between the two [4]:

1. Total commitment to the program by upper-level management is required in both programmes;
2. Employees must be empowered to initiate corrective action;
3. A long-range outlook must be accepted as TPM may take a year or more to implement and is an on-going process. Changes in employee mindset toward their job responsibilities must take place as well.

Table 2 Similarities and Difference Between TQM and TPM [4]

Category	TQM	TPM
Object	Quality (Output and effects)	Equipment (Input and cause)
Mains of attaining the goal	Systematize the management. It is software oriented	Employees participation and it is hardware oriented
Target	Quality for PPM	Elimination of losses and wastes

2.1.2 Motives and uniqueness of TPM

Table 3 shows the motives and uniqueness of TPM.

Table 3 Motives and Uniqueness of TPM [4]

Motives of TPM	1. Adoption of life cycle approach for improving the overall performance of production equipment. 2. Improving productivity by highly motivated workers, which is achieved by job enlargement. 3. The use of voluntary small group activities for identifying the cause of failure, possible plant and equipment modifications.
Uniqueness of TPM	The major difference between TPM and other concepts is that the operators are also made to involve in the maintenance process. The concept of "I (Production operators) Operate, you (Maintenance department) fix" is not followed.

2.2 TPM DEFINITIONS

TPM literature indicates that two main approaches to defining TPM exist, the Western Approach and the Japanese Approach [6] with significant commonality within the two. Bamber [6], in particular, describes the Japanese school of thought represented by Nakajima[7][8] and Shirose [9]. The Western Approach is represented by Willmott [10], Wireman [11] and Hartmann [10]. The Japanese Institute of Plant Maintenance (JIPM) promotes the Japanese approach. Seiichi Nakajima is a vice chairman of JIPM and is considered to be the father of TPM [5].

The following definition will be used to describe total productive manufacturing [5]:

"Total Productive Manufacturing is a structured equipment-centric continuous improvement process that strives to optimize production effectiveness by identifying and eliminating equipment and production efficiency losses throughout the production system life cycle through the active team-based participation of employees across all levels of the operational hierarchy."

Nakajima's definition of TPM is characterized by 5 key elements they are represented in Figure 2 [5].

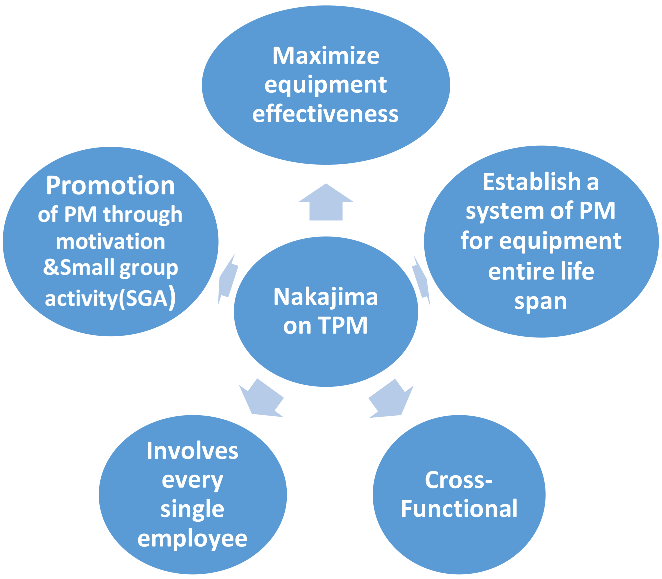


Figure 2 Nakajima's Definition of TPM [5]

Shirose's Definition of TPM is characterized by 5 key elements they are represented in Figure 3 [9].

Figure 3 Shirose Definition of TPM [5]

2.3 TPM BASIC CONCEPTS AND STRUCTURES

Total Productive Manufacturing is a structured equipment-centric continuous improvement process that strives to optimize production effectiveness by identifying and eliminating equipment and production efficiency losses throughout the production system life cycle through the active team-based participation of employees across all levels of the operational hierarchy [5].

2.3.1 The TPM structured continuous improvement process

One of the most significant elements of TPM the structured TPM implementation process is that it is a consistent and repeatable methodology for continuous improvement. "*For world-class competitors, minimal performance requirements include repetitive and predictable year-over-year actual per-unit cost reductions, ever-reducing variation, improved product quality, and extraordinary customer service. Winning requires an institutionalized management proof process that is sustainable despite changes in leadership, strategy, and business conditions-a corporate culture dedicated to manufacturing excellence*." [12].

The principle activities of TPM are organized as pillars. Depending on the author, the naming and number of the pillars may differ slightly, however, the generally accepted model is based on Nakajima's eight pillars as presented in Figure 4 [5].

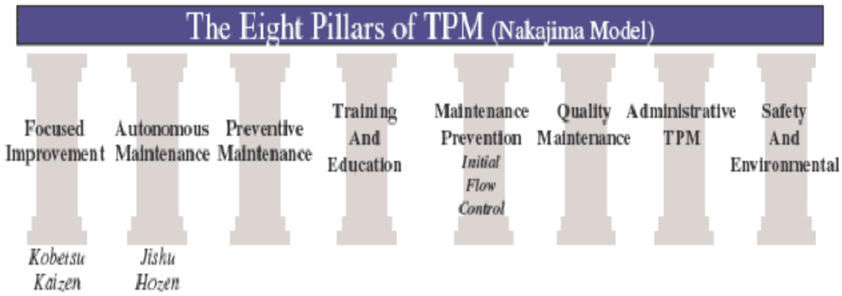


Figure 4 Eight Pillars of TPM (Nakajima Model) [5]

Pillar 1 - Kobetsu-Kaizen - Focused Improvement

"Kai" means change and "Zen" means good (for the better). Basically, kaizen is for small improvements, but carried out on a continual basis and involve all people in the organization. Kaizen is opposite to big spectacular innovations. Kaizen requires no or little investment. The principle behind is that "a very large number of small improvements are more effective in an organizational environment than a few improvements of large value. This pillar is aimed at reducing losses in the workplace that affect our efficiencies. By using a detailed and thorough procedure we eliminate losses in a systematic method using various Kaizen tools. These activities are not limited to production areas and can be implemented in administrative areas as well [4].

Kaizen Policy for focused improvements are shown below [4]:

1. Practice concepts of zero losses in every sphere of activity;
2. Relentless pursuit to achieve cost reduction targets in all resources;
3. Relentless pursuit to improve overall plant equipment effectiveness;
4. Extensive use of PM analysis as a tool for eliminating losses;
5. The focus on the easy handling of operators.

Achieve and sustain zero loses with respect to minor stops, measurement and adjustments, defects and unavoidable downtimes. It also aims to achieve 30% manufacturing cost reduction.

The tools used in Kaizen are listed below [4]:

1. Why - Why analysis;
2. *Poka-yoke* (*Poka-yoke* is Japanese term, which in English means mistake proofing or error prevention);
3. Summary of losses;
4. Kaizen register:
5. Kaizen summary sheet.

The objective of TPM is the maximization of equipment effectiveness. TPM aims at maximization of machine utilization and not merely machine availability maximization. As one of the pillars of TPM activities, Kaizen pursues efficient equipment, operator and material and energy utilization that is extremes of productivity and aims at achieving substantial effects. Kaizen activities try to thoroughly eliminate 16 major losses.

The classification of losses with different aspects and loss, represented in Table 4.

Table 4 Classification of losses [4]

Aspect	Sporadic Loss	Chronic Loss
Causation	Causes for this failure can be easily traced. The cause-effect relationship is simple to trace	This loss cannot be easily identified and solved. Even if various countermeasures are applied
Remedy	Easy to establish a remedial measure	This is caused by hidden defects in machine, equipment and methods
Impact / Loss	A single loss can be costly	A single cause is rare - a combination of causes trends to be a rule
Frequency of Occurrences	The frequency of occurrence is low and occasional	The frequency of loss is more.
Type of analysis required	Why-Why analysis. Here the question 'Why' is queried against the problem five times, within which the solution is reached	The intricate and complex method required This includes cause and effect analysis and correlation analysis
Corrective action	Usually, the line personnel in the production can attend to this problem.	Specialists in process engineering quality assurance and maintenance people are required.

Pillar 2 - Jishu Hozen - Autonomous Maintenance

This pillar is geared towards developing operators to be able to take care of small maintenance tasks, thus freeing up the skilled maintenance people to spend time on more value-added activity and technical repairs. By use of this pillar, the aim is to maintain the machine in new condition. The activities involved are very simple nature.

This includes cleaning, lubricating, visual inspection, tightening of loosened bolts etc [4]. Jishu Hozen (JH) policy for autonomous maintenance are shown below [4]:

1. Uninterrupted operation of equipment.
2. Flexible operators to operate and maintain other equipment's.
3. Eliminating the defects at source through active employee participation.

The various steps in autonomous maintenance are listed below [4]:

1. Preparation of employees;
2. Initial cleanup of machines;
3. Take countermeasures;
4. Fix tentative JH standards;
5. General inspection;
6. Autonomous inspection;
7. Standardization.

Each of the above steps is discussed in detail below:

1. Preparation of employees: educate the employees about TPM, Its advantages, JH advantages and Steps in JH. Educate the employees about the equipment they use, the frequency of oiling, day-to-day maintenance activities required and the abnormalities that could occur in the machine and way to find out the abnormalities.
2. Initial cleanup of machines:
   - Arrange all items needed for cleaning;
   - On the arranged date, employees clean the equipment with the help of the maintenance department;
   - Dust, stains, oils and grease has to be removed. When cleaning oil leakage, loose wires, unfastened nuts and worn out parts must be taken care;
   - After cleaning up, problems are categorized and suitably tagged. White tags are placed where operators can solve problems. The pink tag is placed where the aid of maintenance department is needed;
   - Make note of area, which is inaccessible;
   - Open parts of the machine are closed, and the machine is run.
3. Take countermeasures:
   - Inaccessible regions had to be reached easily. E.g., if there are many screws to open a flywheel door, hinge door can be used. Instead of opening a door for inspecting the machine, acrylic sheets can be used;
   - To prevent work out of machine parts necessary action must be taken. Machine parts should be modified to prevent accumulation of dirt and dust.
4. Fix tentative JH standards:
   - JH schedule has to be made and followed strictly;
   - The schedule should be made regarding cleaning, inspection and lubrication and it also should include details like when what and how.

5. General inspection:
    - The employees are trained in disciplines like pneumatics, electrical, hydraulics, lubricant and coolant, drives, bolts, nuts and safety:
    - This is necessary to improve the technical skills of employees and to use inspection manuals correctly;
    - After acquiring this new knowledge, the employees should share this with others;
    - By acquiring this new technical knowledge, the operators are now well aware of machine parts.
6. Autonomous Inspection:
    - New methods of cleaning and lubricating are used:
    - Each employee prepares his own autonomous chart/schedule in consultation with the supervisor;
    - Parts, which have never given any problem, or part, which don't need any inspection, are removed from the list permanently based on experience;
    - Including good quality machine parts. This avoids defects due to poor JH;
    - The inspection that is made in preventive maintenance is included in JH. The frequency of cleanup and inspection is reduced based on experience.
7. Standardization:
    - Up to the previous step only the machinery/equipment was the concentration. However, in this step, the surroundings of the machinery are organized. Necessary items should be organized, such that there is no searching and searching time is reduced;
    - The work environment is modified such that there is no difficulty in getting any item;
    - Everybody should follow the work instructions strictly;
    - Necessary spares for equipment are planned and procured.

Pillar 3 - Planned Maintenance

It is aimed to have trouble free machines and equipment's producing defect-free products for total customer satisfaction. This breaks maintenance down into 4 families or groups which was defined earlier:

1. Preventive Maintenance
2. Breakdown Maintenance
3. Corrective Maintenance
4. Maintenance Prevention

With Planned Maintenance, we evolve our efforts from a reactive to a proactive method and use trained maintenance staff to help train the operators to better maintain their equipment [4].

Policy for Planned Maintenance is shown below [4]:

- Achieve and sustain the availability of machines
- Optimum maintenance cost.
- Reduces spares inventory.
- Improve reliability and maintainability of machines.

The Major Targets for Planned Maintenance are [4]:

- Zero equipment failure and break down.
- Improve reliability and maintainability by 50 %.
- Reduce maintenance cost by 20 %.
- Ensure availability of spares all the time.

Six steps in Planned Maintenance are mentioned below [4]:

1. Equipment evaluation and recording present status.
2. Restore deterioration and improve a weakness.
3. Building up information management system.
4. Prepare time-based information system, select equipment, parts and members and map out plan.
5. Prepare predictive maintenance system by introducing equipment diagnostic techniques and
6. Evaluation of planned maintenance.

Pillar 4 - Training And Education

It is aimed to have multi-skilled revitalized employees whose morale is high and who was eager to come to work and perform all required functions effectively and independently. Education is given to operators to upgrade their skill. It is not sufficient to know only Know-How but they should also learn know-why. By experience, they gain, Know-How to overcome a problem what to be done. This they do without knowing the root cause of the problem and why they are doing so. Hence it becomes necessary to train them on knowing Know-why. The employees should be trained to achieve the four phases of skill. The goal is to create a factory full of experts. The different phase of skills is [4]:

1. Do not know;
2. Know the theory but cannot do;
3. Can do but cannot teach;
4. Can do and also teach.

The main policy in Education and Training are [4]:

1. Focus on improvement of knowledge, skills and techniques;
2. Creating a training environment for self-learning based on felt needs;

3. Training curriculum/tools/assessment. Conductive to employee revitalization;
4. Training to remove employee fatigue and make work enjoyable.

The major targets in Education and Training are [4]:

1. Achieve and sustain downtime due to wanting men at zero on critical machines;
2. Achieve and sustain zero losses due to lack of knowledge/ skills/techniques;
3. Aim for 100 % participation in suggestion scheme.

Steps followed in Education and Training are mentioned below [4]:

1. Setting policies and priorities and checking the present status of education and training;
2. Establish a training system for operation and maintenance skill up gradation;
3. Training the employees for upgrading the operation and maintenance skills;
4. Preparation of training calendar;
5. The kick-off of the system for training;
6. Evaluation of activities and study of future approach.

Pillar 5 - Maintenance Prevention Pillar, Initial Flow Control

Maintenance Prevention (MP) refers to design activities carried out during the planning and construction of new equipment, that impart to the equipment high degrees of reliability, maintainability, economy, operability, safety, and flexibility, while considering maintenance information and new technologies, and to thereby reduce maintenance expenses and deterioration losses [9]. The classic objective of MP is to minimize the Life Cycle Cost (LCC) of equipment. Expanding the concept of TPM, MP applies to the design of equipment layout and facilitation as well as new processes and products (design for manufacturability). Leachman identified time-to-market as a critical factor in the life-cycle profitability of new products/processes in the semiconductor industry [13]. Effective Maintenance Prevention supports the reduction of the vertical startup lead-time by improving the initial reliability and reducing the variability of equipment and processes. In large part, MP improvements are based on learning from the existing equipment and processes within the focused improvement, autonomous maintenance, and planned maintenance TPM pillar activities.

One of the goals of MP design is to break free of equipment-centred design mentality by adopting a human-machine system approach [13]. In addition to equipment/process reliability and performance attributes, the systems approach will also look at the man-machine interface as it relates to operability and maintainability and safety [5].

The major targets of MP are [14]:

- New equipment reaches planned performance levels much faster due to fewer startup issues.

- Maintenance is simpler and more robust due to practical review and employee involvement prior to installation.

Pillar 6 - Quality Maintenance

It is aimed towards customer delight through highest quality through defect-free manufacturing. The focus is on eliminating non-conformances in a systematic manner, much like Focused Improvement. We gain an understanding of what parts of the equipment affect product quality and begin to eliminate current quality concerns, then move to potential quality concerns. Quality Maintenance (QM) activities are to set equipment conditions that preclude quality defects, based on the basic concept of maintaining perfect equipment to maintain perfect quality of products. The condition is checked and measured in time series to verify that measure values are within standard values to prevent defects. The transition of measured values is watched to predict possibilities of defects occurring and to take countermeasures beforehand [4].

The main policy in QM are [4]:

1. Defect-free conditions and control of equipment.
2. QM activities to support quality assurance.
3. The focus on prevention of defects at the source.
4. Focus on poka-yoke (foolproof system).
5. In-line detection and segregation of defects.
6. Effective implementation of operator quality assurance.

The major targets in QM are [4]:

1. Achieve and sustain customer complaints at zero.
2. Reduce in-process defects by 50%.
3. Reduce the cost of quality by 50%.

Quality defects are classified as customer end defects and in-house defects. For customer-end data, we have to get data on [4]:

1. Customer end line rejection.
2. Field complaints.
3. In-house, data include data related to products and data related to processing.

QM major steps in data related to products are [4]:

1. Product wise defects.
2. The severity of the defect and its contribution - major/minor.
3. Location of the defect with reference to the layout.
4. Magnitude and frequency of its occurrence at each stage of measurement.
5. Occurrence trend in beginning and the end of each production, process, changes (Like pattern change, ladle/furnace lining, etc).

6. Occurrence trend with respect to restoration of breakdown, modifications, periodical replacement of quality components.

QM major steps in data related to processes are [4]:

1. The operating condition for individual sub-process related to men, method, material and machine.
2. The standard settings/conditions of the sub-process.
3. The actual record of the settings/conditions during the defect occurrence.

Pillar 7- Office TPM

Office TPM should be started after activating four other pillars of TPM (JH, KK, QM, PM). Office TPM must be followed to improve productivity, efficiency in the administrative functions and identify and eliminate losses. This includes analyzing processes and procedures towards increased office automation. Office TPM addresses twelve major losses. They are [4]:

1. Processing loss.
2. Cost loss including in areas such as procurement, accounts, marketing, sales leading to high inventories.
3. Communication loss.
4. Idle loss.
5. Set-up loss.
6. Accuracy loss.
7. Office equipment breakdown.
8. Communication channel breakdown, telephone and fax lines.
9. Time spent on retrieval of information.
10. Non-availability of correct online stock status.
11. Customer complaints due to logistics.
12. Expenses on emergency dispatches/purchases.

A senior person from one of the support functions e.g. head of finance, purchase, etc., should be heading the sub-committee. Members representing all support functions and people from Production&Quality should be included in subcommittee. TPM co-ordinate plans and guides the subcommittee [4].

The main Kobetsu Kaizen topics for office TPM are [4]:

1. Inventory reduction.
2. Lead time reduction of critical processes.
3. Motion & space losses.
4. Retrieval time reduction.
5. Equalizing the workload.

6. Improving office efficiency by eliminating the time loss on retrieval of information, by achieving zero breakdowns of office equipment like telephone and fax lines.

The major Kobetsu Kaizen benefits for office TPM are [4]:

1. Involvement of all people in support functions for focusing on better plant performance.
2. Better utilized work area.
3. Reduce repetitive work.
4. Reduced inventory levels in all parts of the supply chain.
5. Reduced administrative costs.
6. Reduced inventory carrying a cost.
7. Reduction in number of files;
8. Reduction of overhead costs (to include the cost of non-production/non-capital equipment).
9. The productivity of people in support functions;
10. Reduction in the breakdown of office equipment;
11. Reduction of customer complaints due to logistics;
12. Reduction in expenses due to emergency dispatches/purchases;
13. Reduced manpower;
14. Clean and pleasant work environment.

This is essential, but only after done as much as possible internally. With suppliers it will lead to on-time delivery, improved 'in-coming' quality and cost reduction. With distributors, it will lead to accurate demand generation, improved secondary distribution and reduction in damages during storage and handling. In any case, it is necessary to teach them based on experience and practice and highlight gaps in the system which affect both sides. In case of some of the larger companies, they have started to support clusters of suppliers [4].

Pillar 8 - Safety, Health and Environment

In this area, focus is on to create a safe workplace and a surrounding area that is not damaged by our process or procedures. This pillar will play an active role in each of the other pillars on a regular basis. A committee is constituted for this pillar which comprises a representative of officers as well as workers. The committee is headed by Senior vice President (Technical). Utmost importance to Safety is given in the plant. Manager (Safety) is looking after functions related to safety. To create awareness among employees’ various competitions like safety slogans, Quiz, Drama, Posters, etc. related to safety can be organized at regular intervals.

The TPM Safety and the Environmental pillar are equally, if not more, important than the seven others. Shirose describes safety as the maintenance of the peace of mind [9]. No TPM program is meaningful without a strict focus on safety and environmental concerns. Ensuring equipment reliability, preventing human error, and eliminating accidents and pollution are the key tenets of TPM [15]. Suzuki provides examples of how TPM improves safety and environmental protection [5].

The major targets of safety, health and environment are [5]:

1. Faulty or unreliable equipment is a source of danger to the operator and the environment. The TPM objective of zero-failure and zero-defects directly supports zero-accidents.
2. Autonomous maintenance teaches equipment operators how to properly operate equipment and maintain a clean and organized workstation.
3. TPM-trained operators have a better understanding of their equipment and processes and are able to quickly detect and resolve abnormalities that might result in unsafe conditions.
4. Operation of equipment by unqualified operators is eliminated through effective deployment of TPM.
5. Operators accept responsibility for safety and environmental protection at their workstations.
6. Safety and environmental protection standards are proliferated and enforce as part of the TPM Quality Maintenance pillar.

Implementing the TPM Safety and Environmental pillar focuses on identifying and eliminating safety and environmental incidents. According to the Heinrich Principle [15], for every 500,000 safety incidents there are 300 “near misses”, 29 injuries, and 1 death. Investigating industrial accidents, Heinrich found that 88% of accidents where caused by unsafe acts of people, 10% where the result of unsafe physical conditions, and 2% he considered “Acts of God”.

The Main Phases of Safety, Health and Environment are [5]:

1. Normal operation, stable state;
2. Signs of abnormality, the system becomes more and more disordered;
3. Unsteady state, difficult to restore to normal;
4. Obvious danger as a result of failure or abnormality. Damage and injury can still be contained and minimized;
5. Injury and severe damage occur;
6. Recovery after the situation is under control.

Environmental safety is becoming an increasing point of focus on TPM implementation. “Manufacturing management in the 21st century will not be effective if the environmental issues are ignored. Manufacturing management that does not take environmental issues into consideration will be removed from society. One of the causes of environmental issues is that industries, academic institutions, and government agencies have been specialized in research, development, promotion, and diffusion of design technologies to produce more artificial products. There is very little concern about setting conditions for equipment to the most favorable ones after it is put into operation or diagnostic techniques to maintain those conditions."

Ichikawa proposes that TPM address the following key environmental objectives within the Safety and Environmental pillar [16]:

1. Construct an Environmental Management System (EMS) that integrates environmental issues as a system. This objective is consistent with ISO14001/14004;
2. Implement activities, through the TPM program, to reduce the environmental impact of manufacturing operations;
3. Create systems to reduce the environmental impact of manufacturing product and process development;
4. Enhance the environmental awareness and education of all employees.

2.3.2 Overall Equipment Effectiveness

Overall Equipment Effectiveness (OEE) is the TPM metric for measuring equipment effectiveness or productivity. "A company cannot make business gains solely by using cost cutting measures because it cannot cut costs enough to become a world-class competitor. Instead, it must invest resources in productivity improvement. This generally increases factory throughput and cuts cost at the same time" [16]. Variations for calculating OEE are in use, however, most are consistent in identifying three major elements of OEE [5]:

1. Availability – the effectiveness of the operation to make equipment available to perform production activity.
2. Performance – the effectiveness of the operation to execute production activity during the period of time that equipment is Available and able to perform those activities.
3. Quality – the effectiveness of the operation to produce units that meet production quality specifications during the period of time that equipment is performing production activity.

OEE is the most effective measure for driving plant improvement. It continuously focuses the plant on the concept of 0-waste [16]. Unless careful monitoring occurs, the reduced capacity goes unnoticed or is accepted as normal. The classic definition of OEE has been used throughout many industries. The definition of OEE is illustrated in Figure

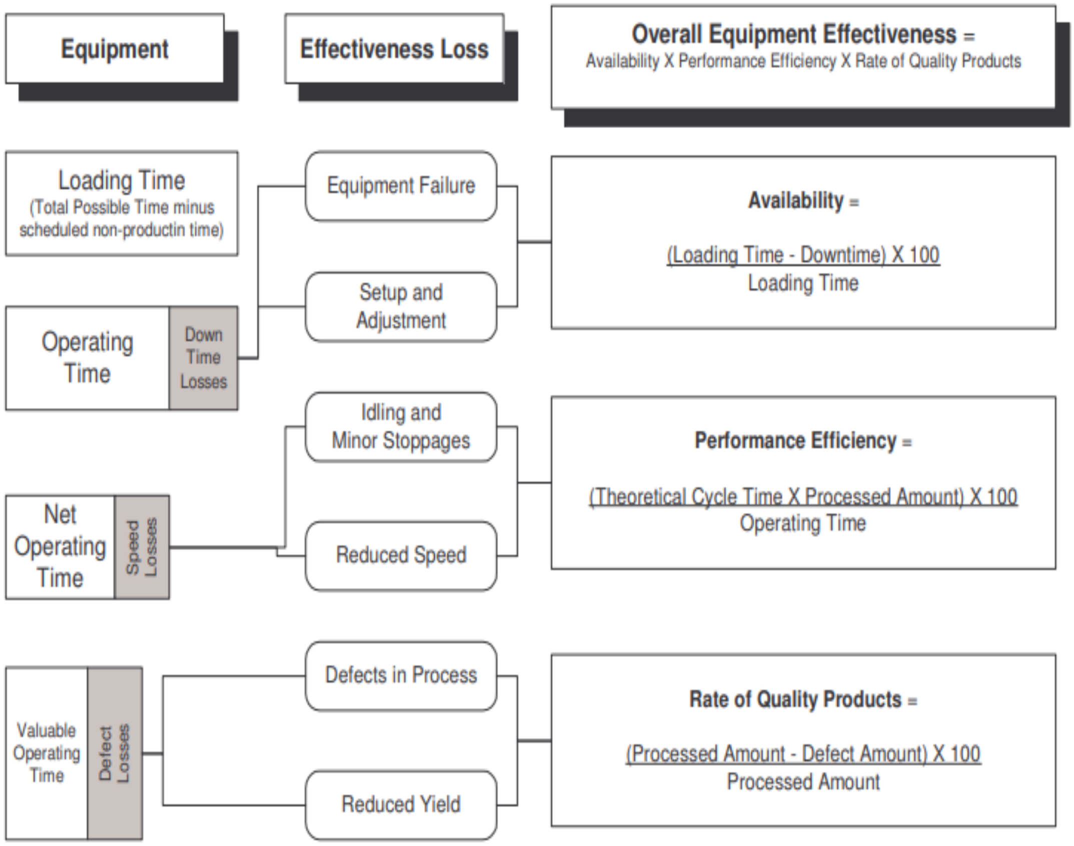


Figure 5 Overall Equipment Effectiveness Calculation and Losses (Nakajima Method) [5]

Note that in this OEE calculation, the scheduled non-production time is removed from the denominator for the Availability calculation. This, in effect, removes these scheduled non-production losses from the OEE calculation. With its high capital investment in production equipment necessitating a focus on equipment productivity, the semiconductor industry has created an alternative productivity calculation known as Overall Equipment Efficiency SEMI [17]. This calculation differs from the classic OEE calculation in that:

1. OEE is based on total potential production hours; and
2. The Elements of the calculation are stated in terms of time (rather than units) to measure efficiency rather than effectiveness.

The SEMI OEE calculation, as illustrated in Figure 6, is based on standard semiconductor industry accepted equipment states [5].

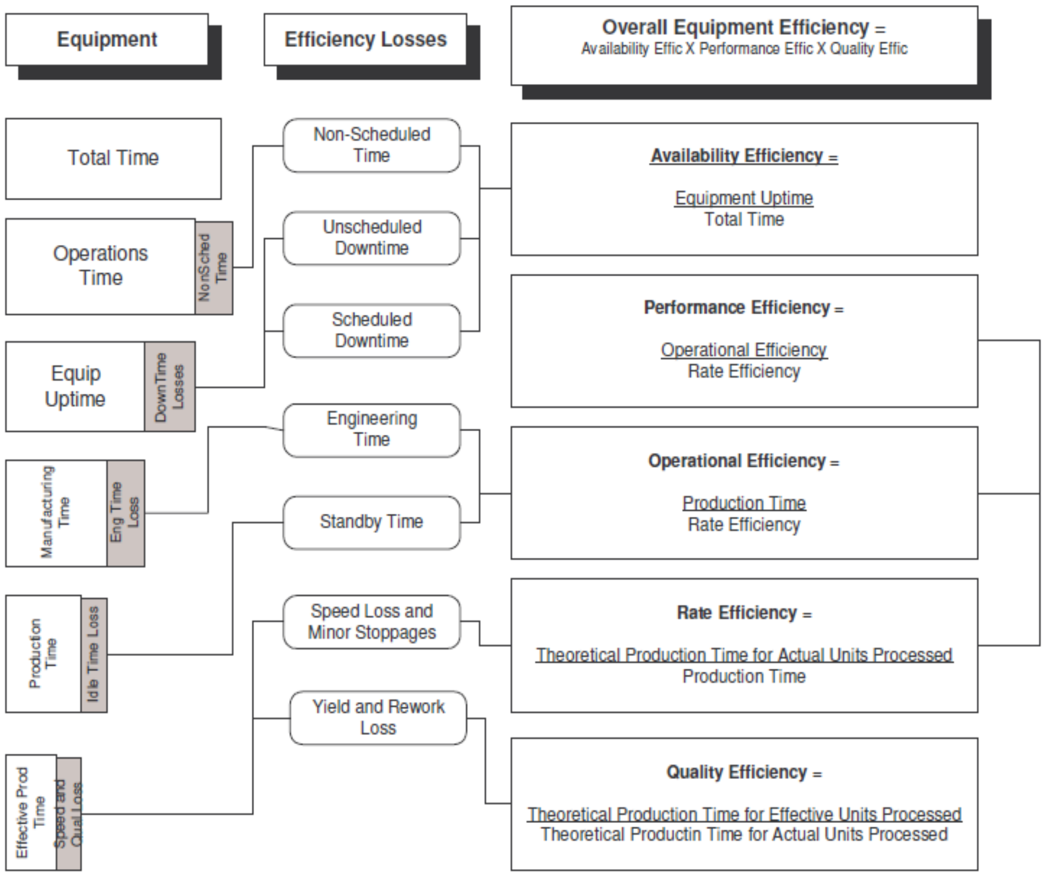


Figure 6 Overall Equipment Efficiency Calculation and Losses (SEMI Method)[5]

When only the value of OEE is required, the OEE calculation can be simplified to:

OEE = Good Units Produced÷ Potential Units Produced [for the time period] → (1)

where Potential Units Produced = Total Time × Potential Units per Hour [for the time period] and Potential Units per Hour = The Number of units that would be produced with no equipment effectiveness loss present.

While OEE presents a high level, a comprehensive measure of equipment effectiveness (efficiency) and productivity, additional metrics are used to fully analyze and understand equipment performance, shuch as [18]:

- Mean Time Between Failure (MTBF).
- Mean Time to Repair (MTTR).
- Production Defect Rate.
- Number of Machine Failures (Failure Rate).
- Equipment Availability.
- Number of Minor Stoppages.
- Production Moves or WIP Turns.
- Production Rate.

- Equipment Setup Time.
- Production Cycle Time.
- PM Time versus Repair Time (Scheduled DT vs. Unscheduled DT).
- Equipment Cpk.
- Number of Equipment Improvements Completed.

2.3.3 Team-based Improvement Activity (Small Group Activity – SGA)

TPM activity is executed by teams known as Small Group Activity (SGA). TPM succeeds not because of its system or engineering techniques but because of its attention to the management of human factors [19]. “A small group is any cross-functional work team charged with working together to improve plant performance by solving problems and managing specific plant areas, machines, or processes.” [20]. TPM SGA involves teams that are part of the standing organization [15]. Suzuki’s TPM structure creates overlapping SGA’s with the membership of one level of SGA becoming the leadership of the next level SGA as shown in Figure 7.

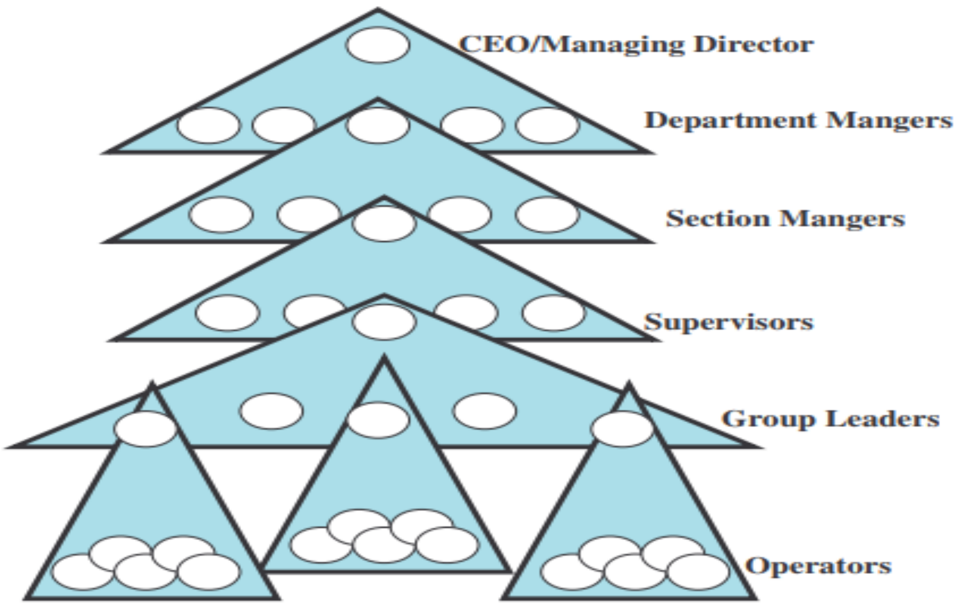


Figure 7 Overlapping Small Group Activity Structure[5]

This structure drives TPM involvement throughout the organization. “Employee involvement is a necessary part of the TPM process. The goal is to tap into the expertise and creative capabilities of the entire plant or facility through the use of small group activities.” [20].

Suzuki provides examples of some common TPM SGA teams [15]:

- **The TPM Promotions Office** – The Promotions Office is responsible to manage the deployment of the TPM program and plays a central role in ensuring that SGA's evolve actively. It is responsible for keeping the TPM program on track.
- **Senior Management Small Groups** – Consist of department or section managers led by senior management. They are responsible for establishing the basic TPM policy and objectives in line with the corporate and site business goals. The Senior Management SGA sponsors the TPM Promotions Office. In the early stages of TPM implementation, the Senior Management SGA performs the first Manager's Model.
- **Middle Management/Supervisor Small Groups** – Section manager or supervisor SGA's responsible for executing the TPM plan within their departments. The Middle Management SGA's sponsor the shop floor Autonomous Maintenance teams.
- **Front-line Small Groups** – Cross-functional shop floor teams that execute the TPM plan within their work areas.

2.3.4 Participation Across All Levels of the Operational Hierarchy

"The Goal of TPM is to maximize the overall effectiveness of the production system through total participation and respect for the individual." [15]. As noted in the previous discussion on SGA's, the top-to-bottom integration of TPM activity is accomplished through interlinking small groups. TPM activities are not voluntary but part of people's daily work [15]. That includes all levels of the organization from top management to the shop floor workers [5].

2.3.4.1 Top-Level Management TPM Responsibilities

"The major issue to successful TPM implementation is manager participation, not just support or commitment, but being fully involved in determining strategy learning the process by doing, coaching others, and assessing progress." [21]. The top-level managers set the high level TPM policies and objectives, create the TPM Promotion Office, and sponsor the TPM Steering Committee. They must also assign the resources to make TPM successful. That success relies, in part, on assigning top performers to roles within the TPM Promotions Office. "Everyone has a lot on their plate and see TPM as something extra, so committing people to the program is tough…along these lines is the need for a TPM Coordinator. This is a must and it should be one of your best people. This is very hard to commit to in most factories" [21].

Top management plays a crucial role in TPM implementation of leading the paradigm shift. "The type of change called for in TPM is especially difficult because in many respects it pervades the fundamental nature of the company's work culture. It reaches through and affects the entire organization." Volker and Farrow recognize that during TPM introduction at Texas Instruments top managers must first change their own culture before leading the change throughout the organization. “The real key is changing the culture of the managers. The top manager is going to want TPM to happen because it makes sense for the business. But the manager cannot just ‘want it to happen’ and continue in his or her job as before. He or she must also change. The manager has to change his/her actions so that TPM becomes something that is expected, not just something that has to be worked on when there is spare time. To the extent that TPM is seen as an additional task, it will fail. It must be seen as the way business is done.” [22].

2.3.4.2 Middle Management TPM Responsibilities

Middle managers are responsible for establishing the departmental TPM policies based on the top management objectives. “This small group has the role of determining the departmental or sectional principles in accordance with basic TPM principles and major targets of the company, of breaking down major targets and having frontline small groups set specific targets” [9]. To effectively guide the shop floor TPM small groups, the middle managers must also actively participate in the TPM activities [15]. They are also responsible for managing their resources to effectively support the TPM activities of the shop floor SGA’s.

2.4 LEAN 6S

Lean 6S is the most popular method to improve the efficiency and safety of any company or organization. The lean 6S method can be implemented in all type of industries or organization like small scale industries, medium scale industries and large-scale industries etc. The 6S is a method for sorting, cleaning, organizing and doing necessary improvement in the workplace. This method helps to increase efficiency and reduces wastage and optimizes the quality of any work environment.

The 6S method gives good results for required improvement in an organization or company. By implementing 6S method we can get good improvement in the production process and safety in any company. The 6S method highly supportive for the objectives of the organization to achieve continuous improvement and higher performance in quality and safety [23].

6S is modeled after the 5S process improvement system designed to reduce waste and optimize productivity in the workplace by [24]:

1. Creating and maintaining organization and orderliness.
2. Using visual cues to achieve more consistent operational results.
3. Reducing defects and making accidents less likely.
4. 6S uses the five pillars of 5S and an added pillar for Safety.

2.4.1 The steps of the 6S method are as follows

The 6S is the methodology of creating and maintaining well organized, neat and clean, high effective, high quality and safer workplace in any organization. The major steps of 6S methods are shown in Table 5.

Table 5 Methodology of 6S [23]

6S Methodology Steps	Japanese terms	Meaning
1. SORT	Seiri	Sort the all useful material and throw away the waste material from the workplace.
2. SET IN ORDER	Seiton	Keep the all things in a proper order and place to quick and easy access to them.
3. SHINE	Seiso	Clean the all machine, equipment and workplace. Maintain the workplace neat and clean regularly.
4. STANDARDIZE	Seiketsu	Uses the standards in the workplace. Constantly keep order at the workplace and make it habitual.
5. SUSTAIN	Shitsuke	Implement this process regularly and make it compulsory for everyone in the workplace.
6. SAFETY	Safety	Install all needed safety equipment at the workplace and make compulsory the wearing of safety equipment at the workplace.

Sorting: Sorting can be classified as throw away all waste material, non-conforming products, useless and damaged tools from the workplace. Keep the all equipment, tools, material and other information that is useful for the attainment of work. It helps to maintain the workplace clean and effective for searching and receiving stuff cut down the time of running the operation [23].

Set in order: Manage the all items in a proper order and place at the workplace for quicker access and use. Place labels on every item for identifying easily.

Make sure items can be recognized by tagging them properly. Every working method has its own type of order. Identify and rectify it [23].

Shine: Routine cleaning makes the workplace neat and clean. The way of cleaning is monitored during cleaning machines, workshop and light source. The operator should take care about own maintenance and cleanness [23].

Standardize: Work out and implanted standards in the workshop. Management should give the instruction to the employees which are easily understandable so workplace clean and would be in order. All workers of the workshop should be participating in this activity. It is concluded that standards not only being implemented in the usual operational process, e.g. maintenance, movement, production, sorting but also in the organizational process like customer service, bookkeeping etc [23].

Sustain: The main objective is to setup a clean environment and to maintain it as an ongoing process forever. This increases the awareness of the workers and increases the quality. It also increases the human relation and workers [23].

Safety: Safety is the main step of the 6S method. Safety is the state of being safe, the condition of being protected from harm. Safety uses some policies and protections to protect the workers from any accidental injury at the workplace. Much safety equipment is also used such as a safety helmet, safety jackets, safety shoes, fire extinguishers etc. in the workplace. Make sure that all safety equipment's like fire extinguishers, personal protective equipment, first aid kit etc. are present at the workplace. All safety equipments should be regularly maintained [23].

2.4.2 Relationship of the 6S Pillars

The relationship of the 6S pillars is explained in Figure 8.

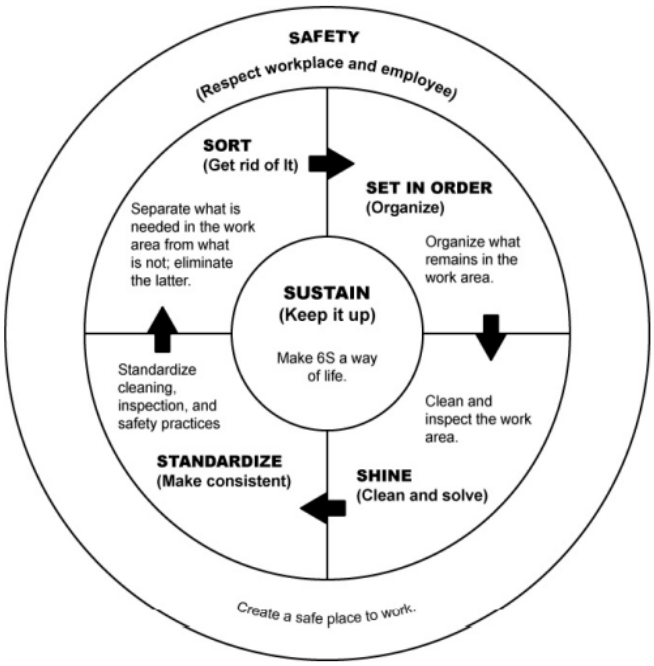


Figure 8 Relationship of the 6S Pillars[24]

2.4.3 The Advantages of using 6S Method are mentioned below[23]:

- Reduction in material handling cost.
- Neat and Clean workplace is available.
- Easy to find tool and use.
- Easy to access all equipment's and files in the organization.
- Saves process time.
- Always neat and clean tools are present at the workplace.
- All things are in well-organized order.
- Increase productivity of the plant.
- Increase the quality of products.
- Reduce the possibility of workers injury.
- Create a safe work environment.
- Improve communication between employees.
- Reduce manufacturing cost.
- Increase workplace safety.
- Increase the efficiency of the plant.
- Increase work speed at the workplace.
- Maximize the use of tools.
- Reduces wastage in the plant.
- Minimizes equipment and tools breakdowns at the workplace.
- Reduces tool changing time.
- Increase workers performance in the workplace.
- Increase the overall efficiency of the workplace.

- Increase workers safety in the workplace.
- Reduces the chances of an accident at the workplace.

2.5 IATF 16949: 2016

The automotive industry is one of the most important sectors of the global economy. It has long been setting new standards not only in quality management (QS 9000/VDA or ISO/TS 16949). It is also an inspiration for seeking efficient production methods, such as lean production, agile production and tools that support such production in the global automotive supply chain. Since October 2016, a new quality management standard in the form of the IATF 16949:2016 system has been in place in the automotive industry. The standard amends the existing ISO/TS 16949:2009 based on the revised ISO 9001:2015 and customer-specific requirements [25].

2.5.1 Prior ISO Technical Specification 16949:2009

The first edition of ISO/TS 16949 was prepared in 1999 by the International Automotive Task Force (IATF) and ISO under the name Quality management systems for automotive suppliers – particular requirements for the application of ISO 9001:9004 with a view to achieving world-wide integration of country-specific assessment and certification systems, i.e. the North American QS 9000, the Italian AVSQ, the French EAQV and the German VDA, with the ISO 9001:9004 standard. Its successive editions (2002, 2009) were essential to keep up with advances in the automotive industry and with amendments to the 2000 and 2008 editions of the ISO 9001 standard. The aim of the existing ISO/TS 16949 was to put in place a global quality management system throughout vehicle, component and part lifecycles to provide for continual improvement emphasizing defect prevention and the reduction of variation and waste in the supply chain (OEM-Tier 1, 2, 3, 4, etc.). The ISO technical specification emphasizes design, planning and production, all of which are subject to the most stringent regulations and require an interdisciplinary approach at every stage. The technical specification calls for a broad approach to analyzing error types and their effects in design, production and logistics failure mode and effects analysis (D/P/L FMEA). It is crucial to document and implement total productive maintenance (TPM) and production instrumentation management systems [25].

2.5.2 Key changes introduced by the new IATF 16949:2016 Standard Relating to Suppliers

IATF 16949:2016 specifies quality management system requirements for the design, development and production and, where applicable, assembly, fitting and servicing, of automotive products, including products with embedded software. IATF 16949:2016 shares the same section headings and clause structure as ISO 9001 and, after its 2015 update, follow the same high-level structure (Supplement SL) with 10 clauses dedicated to ensuring alignment with standards governing other management systems (such as ISO14001 and the ISO27000 series). As opposed to ISO/TS 16949 and other industry standards, IATF 16949:2016 does not contain the ISO 9001:2015 text, which may make it harder to read and understand its requirements (ISO/TS 16949 did cite the text of ISO 9001). To a certain extent, the changes adopted in IATF 16949:2016 reflect those introduced in ISO 9001:2015. Others are either variation on ISO/TS 16949:2009 or all-new issues [25].

The key changes provided in the IATF standard can be summarized as follows [25]:

- Chapter 4 - Context of the Organization
- Chapter 5 - Leadership
- Chapter 6 - Planning
- Chapter 7 - Support
- Chapter 8 - Operation
- Chapter 9 - Performance evaluation
- Chapter 10 - Improvement

2.5.3 The transition from ISO/TS 16949:2009 to IATF 16949:2016

In keeping with the IATF-published strategy of transition from ISO/TS 16949:2009 to IATF 16949:2016, which accounts for the possibility that certain organizations may already be certified to the old editions of VDA 6.1 and ISO 9001:2008, IATF defined detailed transition rules and the related requirements for both certification bodies and organizations seeking an IATF 16949:2016 certificate [Figure 9]. For organizations seeking new IATF certification, the transition will take 23 months from the publication of the new standard to the expiry of ISO/TS certificates on September 14, 2018. Post October 1, 2017, no audits (initial, surveillance, recertification or transfer) may be conducted to ISO/TS 16949:2009 [25].

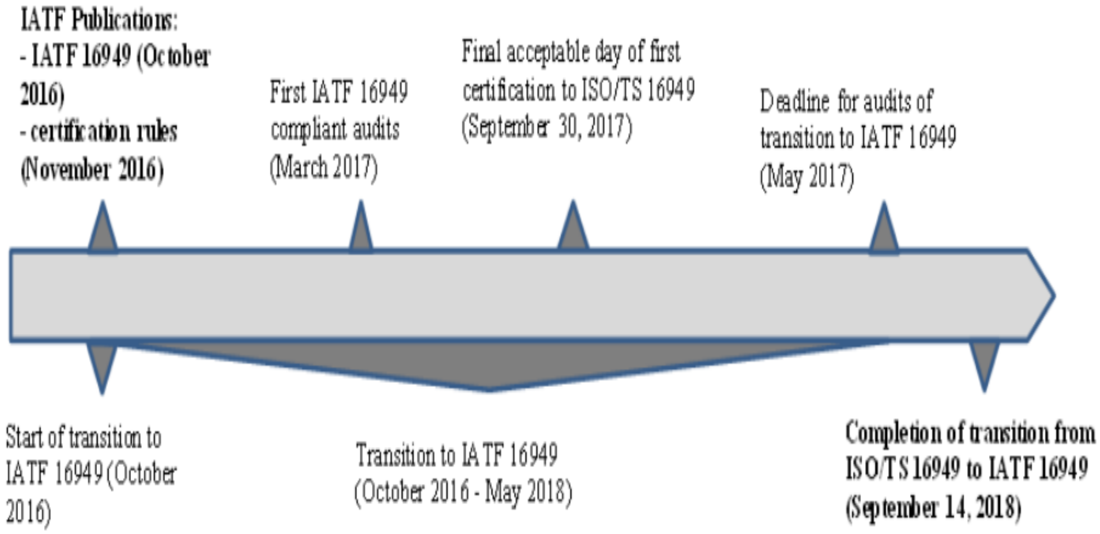


Figure 9 Timing of transition from ISO/TS:16949 to IATF:16949 (Tuv-Sud, 2016) [25]

Organizations certified to ISO/TS 16949:2009 should transition to the new IATF 16949 through a transition audit in line with the current audit cycle for ISO/TS 16949:2009 (i.e. at a regularly scheduled recertification or surveillance audit). Assuming that all prerequisites are satisfied (proof of an organization's compliance with IATF 16949 requirements, auditor qualifications, etc.), organizations may begin their transition in October 2016 [25].

No.	Thematic scope of task	Responsible	Deadline - year/month																								Progress achieved
			2016			2017												2018									
			10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	
1.	Purchase ISO 9000, 9001 standards, 2015 edition, and IATF:2016		■	■	■																						
2.	Familiarize yourself with the standards and demands for transition to IATF:2016				■	■	■	■																			
3.	Hold internal training including change timeline analysis						■	■	■																		
4	Appoint team to analyze gaps and prepare plan for transition from ISO/TS to IATF						■	■	■																		
5	Prepare changes to system documentation based on gaps								■	■	■	■	■														
6	Train personnel and internal auditors regarding changes in system							■	■	■	■																
7	Implement changes								■	■	■	■	■	■													
8	Carry out internal audits									■	■	■	■	■	■												
9	Conduct management overview and agree transition audit date with certification authority														■	■	■	■									
10	Conduct transition audit																■	■	■								
11	Implement audit recommendations																	■	■								
12	Obtain IATF certificate																		■	■							

Figure 10 Draft schedule of transition from ISO/TS:16949:2009 to IATF:16949:2016 compliance[25]

Based on their own experience of cooperation with the automotive industry, the authors propose the following draft plan of transition shown in Figure 10. The draft plan covers such matters as purchases of new editions of ISO standards, IATF 16949 and an online purchase of the standard of transition to IATF:2016 (IATF 2016). Next one should familiarize oneself with ISO 9000 and ISO 9001, IATF 16949 and the strategy of transition to the IATF standard (IATF 2016, ISO 2015). This can be achieved by way of internal training offered to selected employees. The change schedule can be agreed with the certification body. An essential part of the transition should be to appoint the organization's internal team tasked with analyzing gaps in the existing system against the new requirements and formulating a transition plan in consultation with the certification body.

An essential part of the transition should be to appoint the organization's internal team tasked with analyzing gaps in the existing system against the new requirements and formulating a transition plan in consultation with the certification body. The team should not only identify gaps but also coordinate the preparation and supplementation of system documentation by accounting for changes. Another essential step should be to hold internal training for the organization's functions in which system documentation was changed, the aim is to deploy the changes and carry out internal audits. If the audit and management review results are positive, the organization may agree the date and scope of transition audit and system certification to IATF16949:2016 with the certification body.

2.5.4 About IATF 16949:2016

IATF 16949:2016 is all about:

- IATF 16949:2016 (1st edition) represents an innovative document, given a strong orientation to the customer, with the inclusion of a number of consolidated previous customer specific requirements.
- ISO/TS 16949 (1st edition) was originally created in 1999 by the International Automotive Task Force (IATF) with the aim of harmonizing the different assessment and certification systems worldwide in the supply chain for the automotive sector. Other revisions were created (2nd edition in 2002, and 3rd edition in 2009) as necessary for either automotive sector enhancements or ISO 9001 revisions. ISO/TS 16949 (along with supporting technical publications developed by original equipment manufacturers [herein referred to as OEMs] and the national automotive trade associations) introduced a common set of techniques and methods for common product and process development for automotive manufacturing worldwide.
- In preparation for migrating from ISO/TS 16949:2009 (3rd edition) to this Automotive QMS Standard, IATF 16949, feedback was solicited from certification bodies, auditors, suppliers, and OEMs to create IATF 16949:2016 (1st edition), which cancels and replaces ISO/TS 16949:2009 (3rd edition).
- The IATF maintains strong cooperation with ISO by continuing liaison committee status ensuring continued alignment with ISO 9001 [26].

2.5.5 Benefits of IATF 16949:2016

The benefits of IATF 16949 cannot be overstated; companies large and small have used this standard to great effect, discovering and securing tremendous cost and efficiency savings. The new standard will help you to introduce an integrated approach with other management system standards. It will bring quality and continual improvement into the heart of the organization. It will increase the involvement of the leadership team. It will help to mitigate risk and improve opportunity management with a greater application of risk-based thinking. One of the major changes in IATF 16949:2016 is that it brings quality management and continual improvement into the heart of an organization. This means that it can be used to help enhance and monitor the performance of an organization, based on a higher-level strategic view. Here are just a few of these benefits [27]: -

- Improve your image and credibility
- Qualify to supply the automotive industry
- Improve customer satisfaction
- Fully integrated processes
- Use evidence-based decision making
- Create a culture of continual improvement
- Engage your people
- Facilitate continual improvement
- Increase market opportunities

2.5.6 IATF 16949:2016 contains detailed supplementation for the automotive industry, including significant changes regarding:

IATF 16949:2016 contains detailed supplementation for the automotive industry, including significant changes regarding are[25]:

1. The adoption of the top-level management structure, which is binding under ISO 9001:2015.
2. The understanding and definition of the context of the organization and the related internal and external problems relative to such context, resulting from risk and opportunity identification.
3. Top management engagement in corporate responsibility policy, including at least an anti-bribery policy, an employee code of conduct and an ethics escalation policy.
4. Increased emphasis on safety-related products and processes.
5. More stringent requirements concerning product traceability to comply with the latest regulatory changes and requirements for products with embedded software.
6. Added requirements related to corporate responsibility.
7. Taking account of the warranty management process.
8. Increased requirements for internal and external auditors.
9. More specific requirements concerning supplier/sub-supplier management and development.

THESIS DEVELOPMENT

3.1 Analysis of sonafi current manufacturing practices

3.2 Iimplementation of tpm and of 6s

3.3 Data analysis

3 THESIS DEVELOPMENT

This chapter describes, briefly, Sonafi company and presents the findings of the present research, which was conducted to answer the stated research problem. The area of discussion will be focused on the area of research objectives.

3.1 ANALYSIS OF SONAFI CURRENT MANUFACTURING PRACTICES

3.1.1 A brief description of the company

Sonafi is an aluminum alloy die-casting company founded in 1951, aimed at the automotive sector, strategically located in the north of Portugal [28].

Sonafi SA, whose logo and fotography are shown in Figure 11 and Figure 12, respectively, is a company dedicated to the injection molding of aluminum alloys, mechanization of small and medium-sized technical parts, design and development of tools (molds and cutting), where they are finished or vibrated), according to the customer's specification, and is currently a first-line supplier with a leading role in the automotive industry.

sonafi

Figure 11 Sonafi Logo[29]

Figure 12 Company Photography[30]

Since 2007, the company has been part of the Brabant Alocast International Group, based in the Netherlands, with the quality of the service as a flag and compliance with delivery deadlines, always emphasizing reliability as well as a constant attitude towards continuous improvement in order to respond quickly and rigorously to market demands.

Sonafi is a company with 67 years of history and is currently a first line supplier with a leading role in the automotive industry. At its facilities, engineering and production capacities are developed to satisfy all customer orders [31].

Sonafi is headquartered in S. Mamede de Infesta, Matosinhos council and Porto district, within a geographical location that is frankly favorable to the commercial transaction. It is located just 5 km from Francisco Sá Carneiro Airport, about 3 km from the City of Porto and approximately 8 km from the port of Leixões and is also surrounded by a network of roads and motorways where it is possible in less than 3 min to be inserted in some of the most important motorways of Portugal, A1, A3 and A4 (Figure 13).

Figure 13 Company Location of Sonafi[32]

It can then be seen that its location is undoubtedly a strategic point since the ease with which it is possible to move its manufacturing and commercial logistics makes of itself a company with leadership capacity in the market of the injected casting sector [28].

Sonafi was founded in 1951 by Société Générale de Belgique was the first foundry factory to be injected in Portugal. After a start with the difficulties inherent in pioneering projects, the great dynamism of management and the creation of a line of products gave rise to very significant growth rates. During this period, and until 1971, by virtue of the industrial policy of the moment, Sonafi had the exclusive of the Die Casting sector [28]. In 1973, the Portuguese group EMINCO acquires the company's capital, along with the appearance of the first competition in the smelter sector in Portugal, which in turn generates an economic crisis [28]. In 1981, Renault entered into force in the national market, SONAFI reformulated its strategy in the market, targeting the automotive industry as its main priority, thus anticipating the expected increase in European competition due to Portugal's imminent accession to the European Common Market [28].In 1986, a new cycle was instituted in the company, which was acquired by the management that was in force at the time, thus initiating a restructuring, leading to a technological injection, in order to be able to embrace other emerging markets, such as gas heating equipment [28]. Two years later (1988) the company decides to abandon the finished products sector, turning definitively only for the injected smelting, taking advantage of to make investments in this sector. Turning again a year the activity that was dedicated to the production of hardware is sold, due to the disparity of quality levels, as well as structural issues [28]. During the period 1992 to 1994, SONAFI benefited from a special restructuring program for the Portuguese casting sector: PEDIP.

In 2001 the international group EuralCom acquires SONAFI, at which time the automation and sophistication increase in characterized, with the consequent increase of production, allowing to some extent to meet the most diverse requirements of the market [28]. Finally, in December 2007 the Brabant Alocast International Group acquires the capital of SONAFI, thus maintaining the company within a European group of injected casting. Since 2010, Sonafi is repurchased by the Macedo family. Business expansion and diversification of customer portfolio Technology investment (precision machining and casting) Automation [31].

The company is organized by departments, which in turn are subdivided into sections. The Organizational structures start with the Chairman’s, whose main function is to establish the objectives of organization and control of the executive action of the general direction. The CEO, in turn, implements the objectives defined by the Board of Directors, thus making the link with the different departments in order to follow the agreed strategy. This strategy is ensured by department heads who monitor and lead a variety of managers and section heads to ensure the value chain defined by management. Figure 14 shows the company organizacional structure.

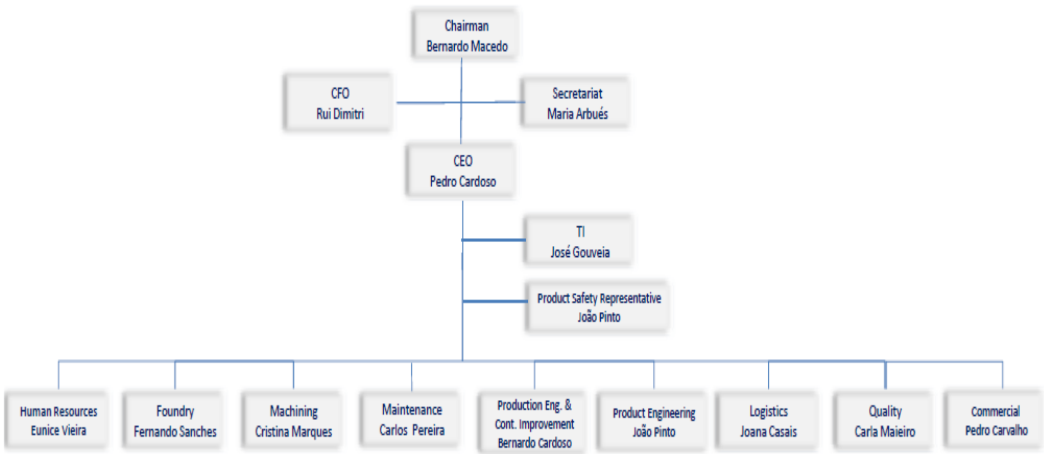


Figure 14 Company Organizational Structure[33]

Sonafis philosophy is based on four essential principles for its sustainability [28]:

- **Organize**, because in order to achieve the objectives of Sonafi each one has to realize its function as part of a group.
- **Innovate**, because only then can you lead an ever-changing world.
- **Develop**, because only the spirit of continuous improvement allows us to ensure continuity.
- **Humanizing,** because man is, after all, the engine of this whole process. Because he is the ultimate beneficiary of his actions and because we understand that in Sonafil, each one counts as an individual and a human being.

ORGANIZE, INNOVATE, DEVELOP HUMANIZING.

"This is our way of being" [28]

3.1.2 Numbers in SONAFI

SONAFI currently uses two different alloys to meet the demands of the market, with different weights in the production plan. In Table 6, the alloys consumed, and their standards are indicated [28].

Table 6 Alloys Consumed by Sonafi [28]

Alloy	DIN standard	Internal Designation	% Consumption (Average)
AlSiCu3(Fe)	NF EN 1706 DIN EN 1706 (EN AC46000)	Violet Alloy	97%
AlSi10Mg	NF EN 1706 DIN EN 1706 (ENAC43100)	Blue Alloy	3%

Like any industry leader, SONAFI is equipped with all the specialist machines, namely, 24 injection machines, 300 to 1400 tons of injection force. It works 6 days/week, 24 hours in the 3-shift regime. In recent years there has been a strong investment in the finishing sector of the company, particularly in the acquisition of more precise and automated machining centers [28]. There are many other equipaments, namely, 15 special transfer machine, 3 suspension machines, 1 drum machine, 4 vibration machines RÖSLER, washing machine, leak detection equipment, accessory mounting machines, test and control equipment and other equipaments.

In the foundry area, they have various types of Die-Casting machines. Two of those types of machines, Buhler and Colosio, are shown in Figure 15 and Figure 16 respectively.

Figure 15 Buhler Die-Casting Machine

Figure 16 Colosio Die-Casting Machine

As referred previousely, SONAFI has several types of CNC machines. Figure 17 and Figure 18 shows the two company prducts used, Chiron and Heller respectively.

Figure 17 Chiron Machining Centers[29]

Figure 18 Heller Machining Centers[34]

SONAFI currently works almost exclusively for the automotive sector, accounting for around 99.9% of its production volume. Figure 19 shows the percentual distribution of the products produced [28].

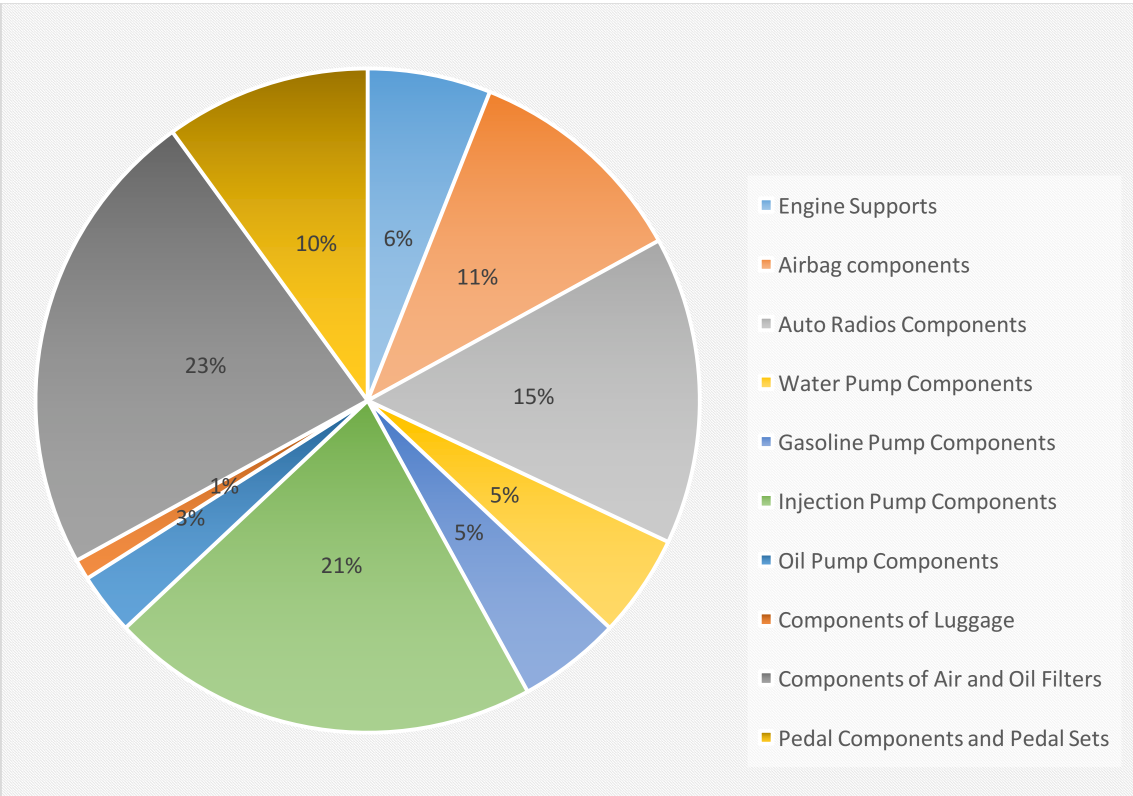


Figure 19 Parts Produced by Sonafi

The various products produced by Sonafi are shown in Figure 20.

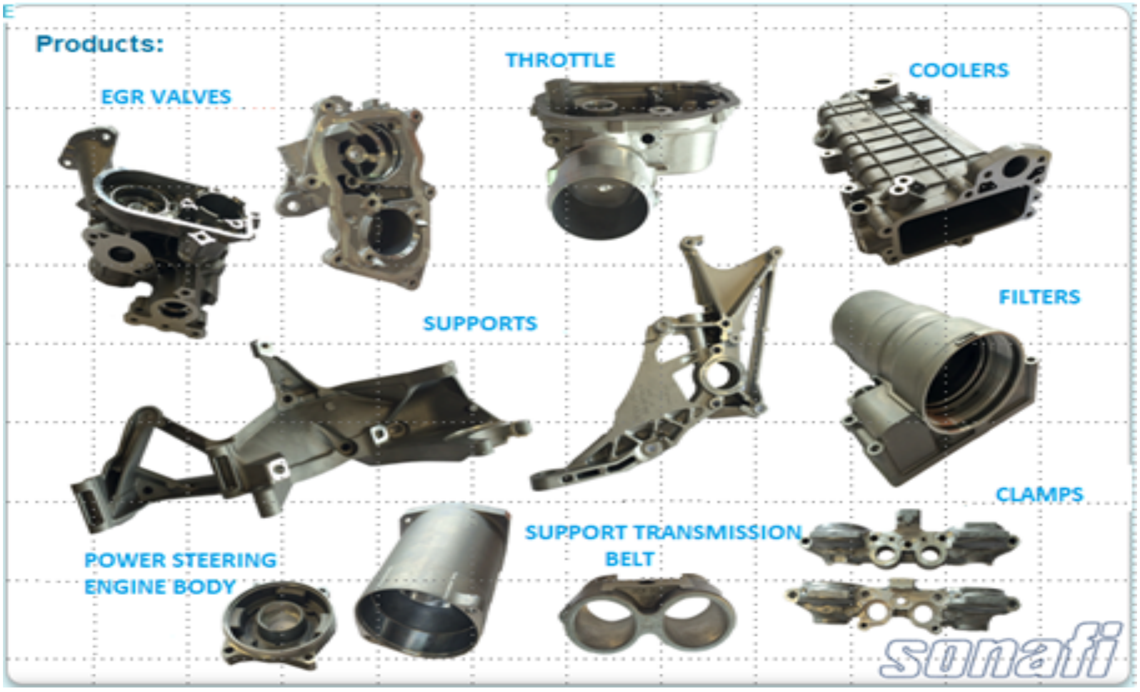


Figure 20 Products of Sonafi [31]

Having as a main expression the international market, absorbing a great part of the production, SONAFI also appears in the national market, obtaining a panoply of clients that give body to its organization, such as shown in Figure 21.

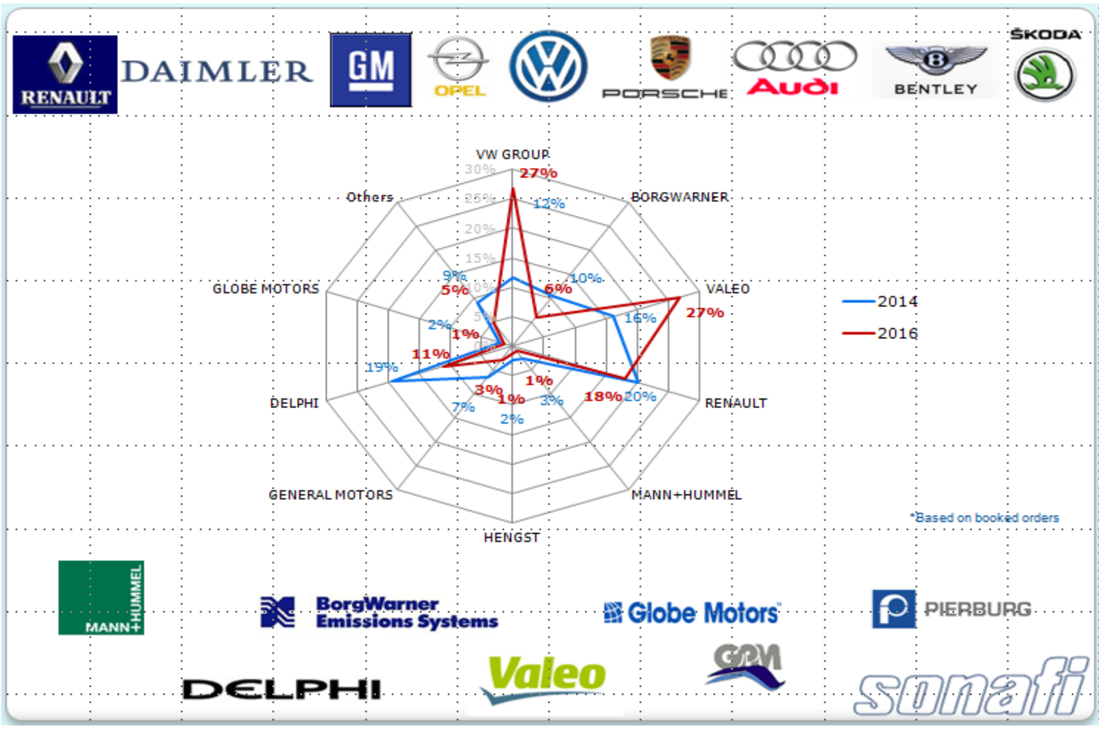


Figure 21 Customers of Sonafi [31]

3.1.3 Company Layout

Being the company divided into sectors as distinct as engineering, financial, production, human resources, the focuss will be the one that has more interest to the work developed and that assumes as the heart of the whole organization. The company model layout of Sonafi has shown in Figure 22.

The plant is divided into 6 sections: fusion, casting 1, casting 2, machining area 1, machining area 2 and renault machining area:

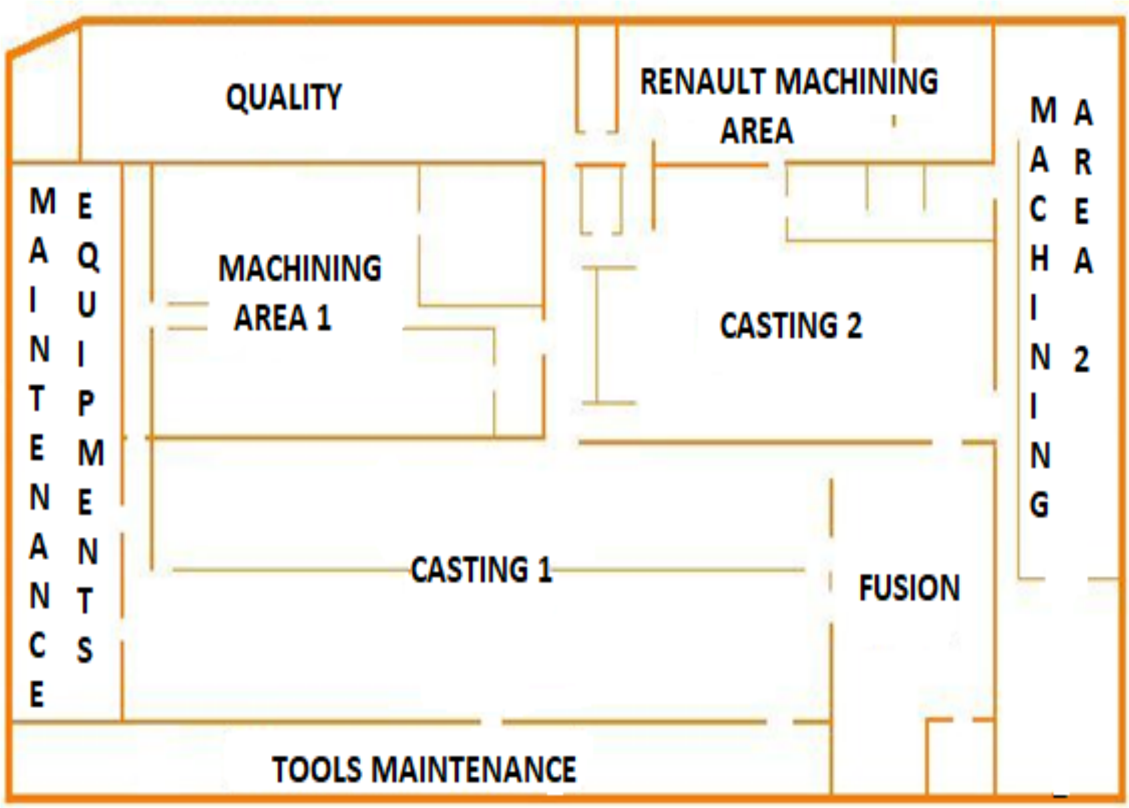


Figure 22 Company Layout of Sonafi[28]

The melting zone is the zone where the whole production process starts, there being three dry-gas-fired ovens. Each furnace is only used for the melting of a particular alloy in order not to contaminate the melting baths. The feed of these is made through ingots and returns of the foundry that are reused such as gitos, masselotes, defective pieces among others. After the melting of the aluminum, it is taken to a machine whose mission is to degas the alloy, and to reduce the degree of impurities present through the addition of nitrogen and slagifier. The Sample of Melting Furnace is shown in Figure 23 [28].

Figure 23 Melting Furnace[28]

The foundry area is divided into two sections. Foundry area of Section 1 is shown in Figure 24. Each of the machines is equipped with an electric maintenance oven, as well as a hydraulic press whose function is to cut the gypsum of the castings. This process is performed by a "robot" in order to significantly reduce the cycle time of each part. In turn, the feeding of machines in some sectors is done by automated spoons, hydraulic arms, or gutters, where aluminum reaches the piston liners by gravity. As a sign of the relevance given to quality by Sonafi, in each machine there is a dimensional control station that is carried out twice per shift, as shown in Figure 25 [28].

Figure 24 Foundry Area of Sonafi[28]

Figure 25 Post of Dimensional Control [28]

In the machining sector, fully automated machining centers are available, where the robot takes a leading role within each of the existing machining centers. Other devices are available to satisfy the customer's desired finish, ranging from shot blenders to vibrators, culminating in the visual and dimensional inspection of all parts without exception. In Machining area of Sonafi has different machines with various brands such as Heller and Chiron. Machining area of SONAFI is shown in Figure 26 [28].

Figure 26 Machining Area of Sonafi [28]

Sometimes in some series, some parts are randomly chosen where more detailed tests are carried out in the search for the smallest defect, through x-ray analysis, as well as leak proof control, using standard parts [28].

3.1.4 Production Process

The following organization chart (Figure 27) succinctly describes the entire SONAFI production process, constituting a chain of operations. It starts from the fusion oven then pass through sensors. From sensors then pass through temperature maintenance fournace to machine injection. From machine, injection is divided into shot blasting and vibration, then sends to machining and washing. From their it sends to dimension control later send to tightness test. The approved products are then delivered to customers.

3.1.5 Die-Casting

Injection casting is a process where high precision light alloy parts, complex shapes and low surface roughness or textured surface finish are created under high pressures [28].

The entire process in the die cast is mechanical in which the molten metal at a temperature above the melting point is poured into a chamber and then compressed/injected into a metal die. This type of process solution allows the manufacture of a high series of parts, where the quality, the dimensional precision, the good finishes and the mechanical resistance are decisive factors [28].

In this process it is possible to obtain pieces weighing between 50g and 20kg, despite a dimensional accuracy that can reach a 0.05mm, being possible to obtain minimum thicknesses of 2.5mm, with roughness values between 0.4 and 3.2µm [28]. Figure 27 shows the example of injected casting part.

Figure 27 Injected Casting Part[28]

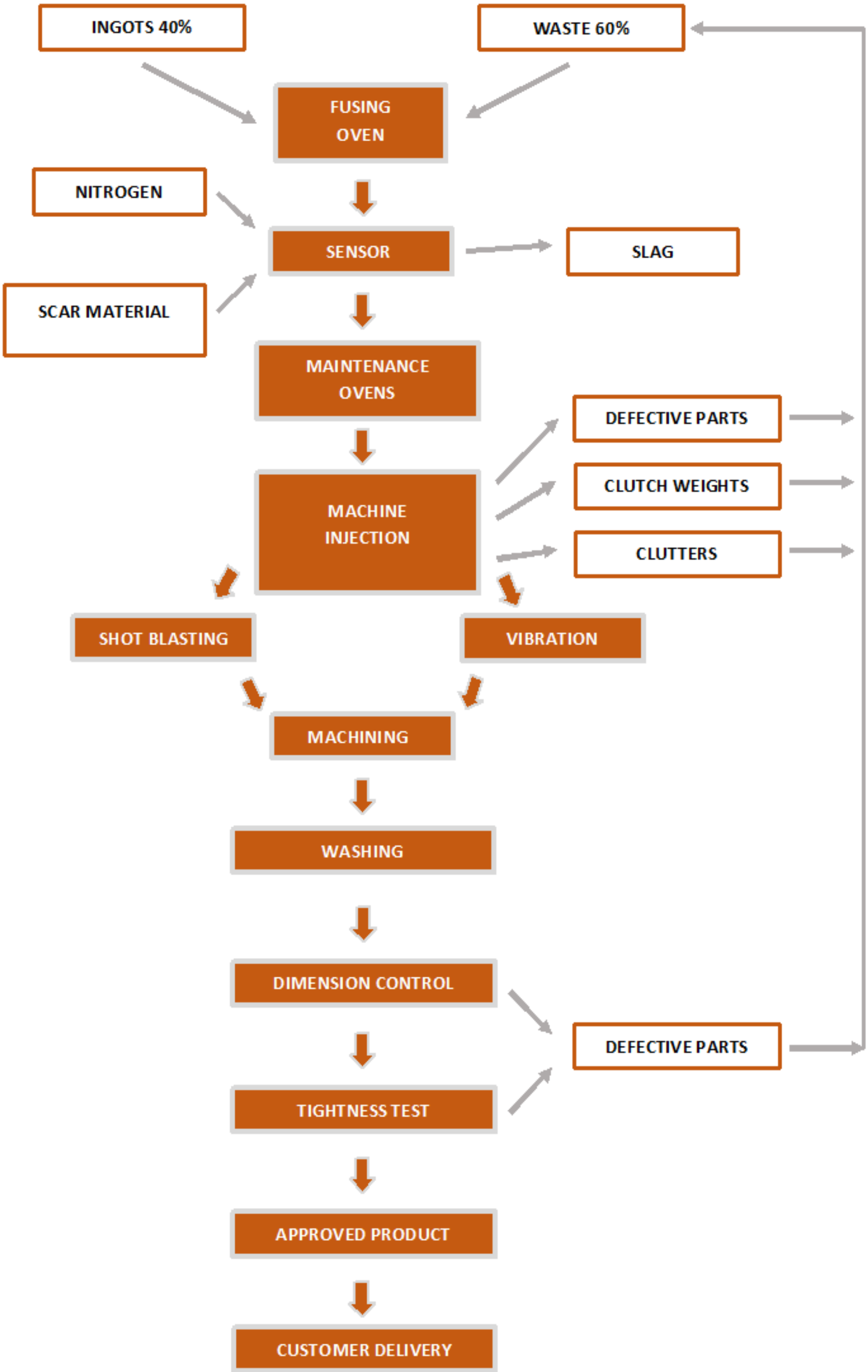


Figure 28 Production Process of Sonafi[28]

Injected casting is a process as stated in Figure 28 where the molten alloy is forced under high pressure to enter a casting at a very high speed. The heat coming from the alloy is transmitted by conduction phenomena for the molding, which in turn is provided with a cooling system whose function is to cool the mold. So, that the alloy solidifies rapidly [28].

All the Injection machines have a maintenance oven (Figure 29), these being in the particular case of SONAFI of electrical operation, its function as the name indicates is to keep the aluminum alloys at temperatures between 650ºC and 700ºC [28].

Figure 29 Maintenance Oven in Die-Casting Industry [28]

An injection is only complete when three injection phases are carried out, with a total duration of approximately 3 seconds, this value being dependent on the size of the part to be injected, the number of cavities available, and the capacity of the injection machine. The whole process begins when a refractory crucible withdraws from the melting furnace a properly dosed portion of the alloy by automatically leaking it into the injection cylinder as shwon in Figure 30, in order to then give the 1st stage.

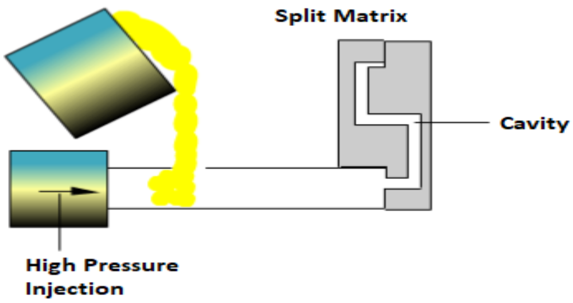


Figure 30 Placing the alloy on the injection cylinder in Graphic View[28]

After the pouring, the injection process itself begins, by approaching the piston to the mold at a low speed, to maintain the flow of alloy under a laminar regime, thereby preventing the mixing of air within the liquid alloy (Figure 31).

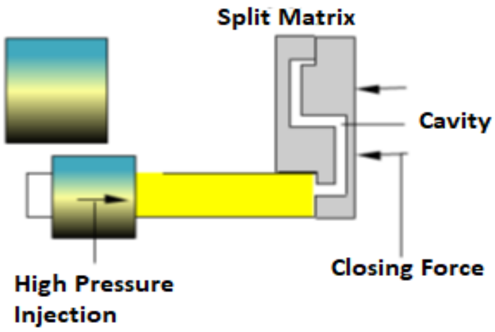


Figure 31 Approach Phase-1st Phase in Graphic View [28]

The second injection phase[Figure 32], commences when the 1st ends when the alloy is at the inlet of the mold, the speed of the piston will accelerate abruptly, leading to a complete filling of all cavities in the mold, this should be at a temperature close to 250°C (for aluminum alloys). This advancement should have two antagonistic characteristics: if on the one hand it should be an extremely fast movement so that there is no possibility of premature cooling of the alloy, on the other hand it should be slow enough to allow time for the expulsion of air from the interior of the through the ventilation holes [28].

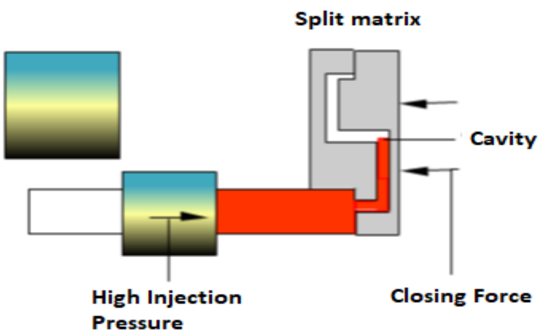


Figure 32 Filing Phase-2nd Phase in Graphic View[28]

At the end of the second stage, which results in the mold cavity being completely filled by the alloy, where it is at a temperature close to the solidification temperature, a high pressure is applied to the piston which will result in the alloy being compacted. This nominal compaction force is a decisive factor in the choice of machine to be used for the production of a particular part, since the injection machines are classified according to the force that they are able to apply to the piston in the third stage of the casting process [28].

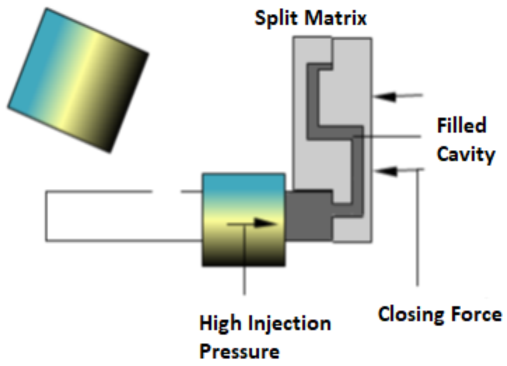


Figure 33 Compaction Phase-3rd Phase in Graphic View[28]

The analysis of the Injection signals, through their typical curves, are of extreme importance to ensure a good quality of the part, both in terms of mechanical properties and in terms of their overall appearance. The phase to which more attention is due will be the second phase, lasting only 100 to 300 ms, due to its brevity, it is possible to trigger or not an early cooling of the alloy, total or partial.In order to make it possible to control and monitor the entire casting process, each machine is provided with transducers which measure various quantities over time thus defining the injection parameters.This entire monitoring system is indexed to a computer which after properly conditioning the signal allows us to withdraw important indications of the entire behavior of an injection over time thereby defining an injection characteristic [28].

The molds used in the die casting industry have an extremely complex appearance, featuring a plurality of mold plate assemblies, cooling systems, control systems which together give rise to a mold itself. Examples of die-casting molds are shown in Figure 34.

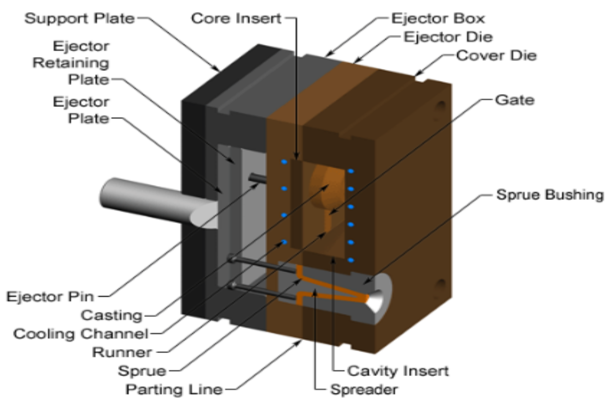


Figure 34 Example of a Die Casting Mold in Graphic View[28]

The molds are formed essentially of two parts, one fixed and one movable, hydraulically moved so that it becomes possible to open and close the mold at the end of each injection, in order to remove the parts at the end of each injection.There in are present one or more cavities connected to each other by channels through which the alloy flows during filling thus constituting the "gito", which is then cut and recycled for further melting [28].

In Figure 35, symbolic representation of 2 cavities present in a mold are shown. Since it is necessary to cool the mold at the end of each injection to maintain it at an ideal operating temperature as well as to cool the part, there are present cooling ducts within which circulate water belonging to the company's closed cooling circuit.

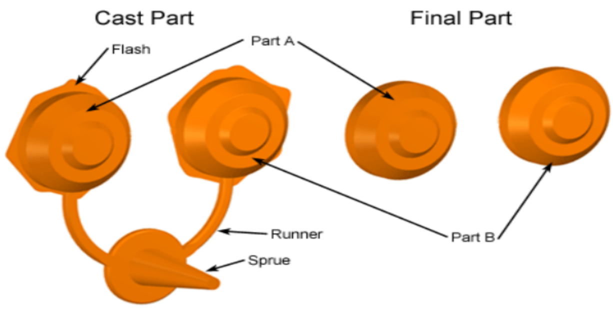


Figure 35 Symbolic representation of 2 cavities present in a mold[28]

3.1.5.1 Types of Injected Foundry

In the process of injected casting we can find two different types of operation, injected casting with hot runner and injected casting with cold chamber, which is subdivided into injected casting with cold chamber and vertical movement and the casting injected with cold chamber and horizontal movement, as shown in Figure 36.

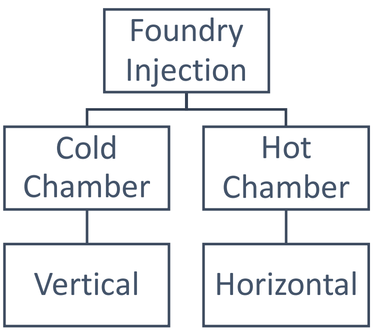


Figure 36 Types of Injected Foundry [28]

The hot-melt die casting process began to gain expression in the 1950s, and "today is a process with very little expression these days". Its working process is distinguished from the cold chamber injected casting due to the existence of a furnace which has in principle to generate and maintain the alloy in the liquid state. The injection chamber is then immersed in the bath and the injection can take place under two processes, by means of driving through compressed air, or by the action of a plunger, mechanisms whose mission is to drive the alloy into the mold in order to fill the entire cavity the same. The mechanism is shown in the following figure [28].

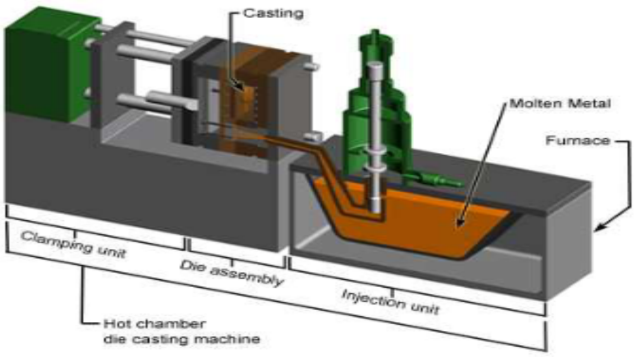


Figure 37 Representation of a Die Casting Machine by Hot Chamber in Graphic View [28]

Cold-chamber die casting, Figure 39, is now the most widely used, mainly due to its large capacity to produce high cadence productions, which can vary its cycles between 150 and 500 cycles per hour. This type of machines can arise with pistons of vertical or horizontal movement, depending on the existing needs. In contrast to hot-melt die casting, it has no built-in furnace inside, because in order to conserve the alloy in its liquid state, auxiliary furnaces are called maintenance furnaces, where, through the aid of a robot equipped with a refractory crucible, portion necessary for each injection of alloy by discharging it into the piston liner which drives the alloy into the cavity.

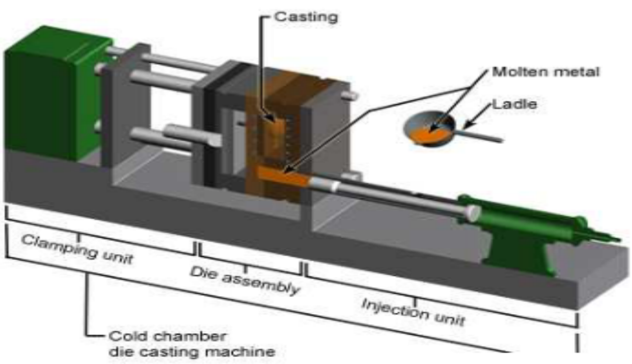


Figure 38 Injection Machine with cold chamber and horizontal movement piston in Graphic View [28]

3.1.5.2 Advantages, disadvantages and requirements

The Advantages of die casting can be described as follows:

1. Very fast process (number of pieces / hour);
2. Reduced number of secondary operations;
3. Good quality parts, appearance and dimensional accuracy;
4. Possibility of using various non-ferrous alloys;
5. Production of parts with tight tolerances;
6. easily obtained outer threads;
7. Possible incorporation of metallic inserts;
8. Parts with good resistance to corrosion;
9. They are easily treated superficially.

The Disadvantages of the die casting are:

1. High cost of equipment;
2. High cost of tools;
3. Limitations to the type of casting alloy;
4. Limiting both the maximum dimension and the geometry of the parts to be obtained.

The injection molding industry should be able to respond promptly to market requirements and therefore all its production should meet high importance criteria such as:

1. Low price (low cost);
2. Good quality;
3. Low porosity indexes;
4. Can be produced with tight tolerances;
5. High cadences;
6. They have a long lifespan.

3.1.6 Major manufacturing Issues

Major manufacturing issues received to ME is Repair and Rework.To avoid this, TPM has to be implemented. The analysis of all departments that comes under ME is done before implementing TPM.

The major problems in foundry maintenance area under ME are:

1. Lack of Training, Motivation and Leadership among workers.
2. Worker turnover is a major concern.

3. Need to improve in equipment available for maintenance preventive.
4. Need to improve in infrastructure, cleaning and organization.

The Major Problems in Machining area under ME are:

1. The principle problems in Machineering area is with compressed air room, leakage and temperature.
2. Organization and Supervision is needed to be improved.
3. Need to improve in space and cleaning.
4. Constant change of workers is a bigger concern.
5. Lack of motivation and training need to be improved.

The Major Problems in Spare Parts Area (Warehouse ME):

1. Lack of space to store all the spare parts.
2. Storage of waste & obsolete.
3. Rain and stagnation of water is a big concern.
4. Maintaining of stocks is still a major problem.
5. Need to improve in formation, cleaning and infrastructure.

3.1.7 TPM Targets

The Major TPM Targets are[4]:

1. Obtain Minimum 90% OEE (Overall Equipment Effectiveness)
2. Run the machines even during lunch. (Lunch is for operators and not for machines!)
3. Operate in a manner, so that there are no customer complaints.
4. Reduce the manufacturing cost by 30%.
5. Achieve 100% success in delivering the goods as required by the customer.
6. Maintain an accident free environment.
7. Increase the suggestions from the workers/employees by 3 times. Develop multi-skilled and flexible workers.

3.2 IMPLEMENTATION OF TPM AND OF 6S

As refered previously, TPM is a maintenance program that involves a newly defined concept for plant and equipment maintenance. The goal of the TPM program is to dramatically increase production while increasing employee morale and job satisfaction:

- The Total implies a comprehensive view of all activities related to equipment maintenance and the impact that each one has upon availability.
- Productive relates to the ultimate goal of the effort, that is, efficient production not only efficient maintenance is often assumed by mistake.
- Maintenance means the directional drive of the program to ensure reliable processes and maintain production [4].

3.2.1 Design of Sonafi TPM Pillars & Flowchart

Design of TPM Pillars and Flowchart are done based on the requirements and expectation of the Sonafi as mentioned in the declaration. The ultimate motive of this design is to increase the OEE.The Design of Sonafi TPM Pillars and Flowchart are shown in Figure 39 and Figure 40:

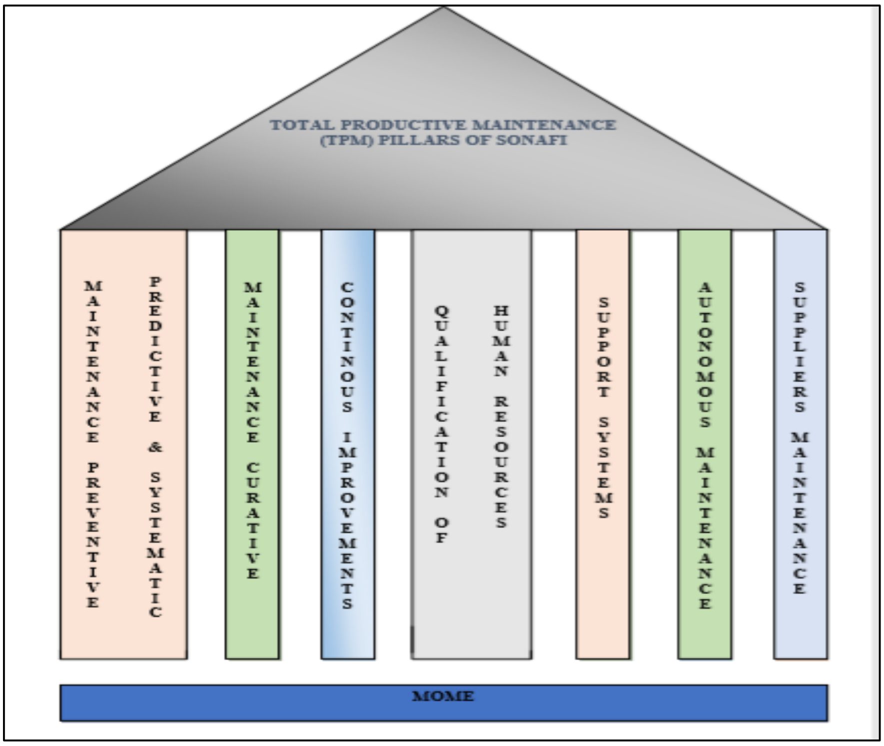


Figure 39 TPM Pillars of Sonafi

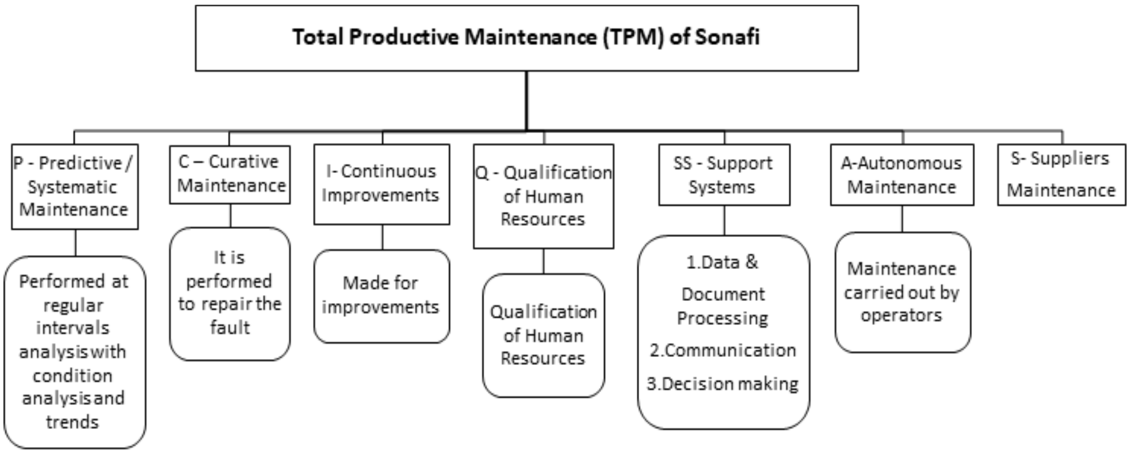


Figure 40 TPM Flowchart of Sonafi

The following is a description of the SONAFI TPM pillars:

1. **Predictive / Systematic Maintenance:**

a) **Predictive maintenance** is a method in which the life of an important part is predicted based on inspection or diagnosis, to use the parts up to the limit of their useful life. In comparison to periodic maintenance, predictive maintenance is condition-based maintenance. It manages trend values, measuring and analyzing deterioration data, and employing a surveillance system, designed to monitor conditions through an online system.

b) **Systematic maintenance:** is a periodic preventive maintenance (cleaning, inspection, oil and re-tightening), design to maintain the healthy condition of the equipment and prevent failures by preventing deterioration, periodic inspection or equipment condition diagnosis, to measure deterioration.

2. **Curative Maintenance:** Improves equipment and components so that preventive maintenance can be performed reliably. Equipment with design weakness should be redesigned to improve reliability or I improve serviceability. This happens at the user level of the equipment.
3. **Continuous improvements:** All processes can be continually improved in terms of time, resources and results.
4. **Qualification of human resources:** The qualification of human resources is the personnel of a company or organization, considered as a significant good in terms of skills and abilities.
5. **Support System:**

- The support system applies TPM activities to continuously improve the efficiency and effectiveness of logistics and administrative functions.
- These logistical and support functions can have a significant impact on the performance of production operations. In line with the vision of a "production

system" that includes not only manufacturing but also manufacturing support functions, TPM must embrace the entire enterprise, including administrative and support departments.

- The major area in support systems are:
    1. Data & Document Processing
    2. Communication
    3. Decision making

6. **Autonomous Maintenance:** Operators of machines that, through routine actions, assure the normal condition of operation of your equipment.
7. **Suppliers Maintenance:** Suppliers Maintenance applies to all subcontracted maintenance services (including equipment and infrastructures) and purchase of equipment maintenance materials.

3.2.2 Maintenance Levels

Sonafi ME has maintenance levels in manual. The manual is updated based on the TPM concepts. Maintenance Levels are divided into 3 types they are:

1. 1st Level of Maintenance
2. 2nd Level of Maintenance
3. 3rd Level of Maintenance

The **first Level of Maintenance** are divided into 3 parts: Nature of Work; Place of Intervention; Execution Staff.

Nature of Work are:

- Renewal of fluids (lubricating and hydraulic oils, nitrogen, etc.);
- Simple adjustments of accessible organs without any disassembly;
- Simple maintenance operations such as pressure, status checks, fuel and fluid level checks and inspections.

Place of intervention:

- On-site equipment is the place of Intervention.

Execution staff:

- Operator is the execution staff of 1st Level of Maintenance.

The **second level of maintenance** are divided into 5 parts: Nature of Work; Place of Intervention; Execution Staff; Maintenance Materials; Documentation Required.

Nature of work:

- Restoration of the operation of the system or equipment, the abnormality of which is usually signaled by a defect- tracking device using the exchange of principal elements.

- General regulations and realignments, delicate periodic operations (eg, control of wear of mechanical organs.
- Exchange of functional units whose abnormality was identified by fault finding devices.
- Restoration of functional units by exchange of elementary articles.
- Minor mechanical repairs

Place of intervention:

- In the location of the equipment or on the main elements moved to a workshop is the Place of Intervention.

Execution staff:

- Equipment Maintenance Technician, Technician able to make a diagnosis about the equipment with the help of appropriate means of locating defects and with good knowledge are the Execution staff.

Maintenance materials:

- Maintenance materials defined by the machine maintenance manual and best practices.
- Materials and programs of programmable automated and industrial computer science.
- Workshop support tool.
- Industrial cleaning and washing equipment
- Test benches.
- Secondary gauges

Documentation required:

- Documents required for 2nd level of maintenance are Maintenance Plans and Manuals of Manufacturers' Equipment.

The **third Level of maintenance** are divided into 5 parts: Nature of Work; Place of Intervention; Execution Staff; Maintenance Materials; Documentation Required

Nature of work:

- Repair and transformation of logical units.
- Great mechanical repairs.
- Specific work on test and measurement equipment used for maintenance (repair, adjustment and calibration).
- Works that require means and industrial know-how.
- General revisions and renovations of equipment and main elements vulgarly designated by revamping, upgrade, redisign.

Place of intervention:

- On the main elements moved to a specialized workshop (Exceptionally where the equipment is installed).
- In the equipment builder are the place of intervention.

Execution staff:

- Technicians who have a good knowledge of the equipment on which they have to intervene as well as the corresponding maintenance means.
- Personnel of the builder of the equipment or maintenance personnel of equipment with specific knowledge are the execution staff.

Maintenance materials:

- Materials and programs of programmable automata and industrial computer science.
- Workshop support tool.
- Industrial cleaning and washing equipment
- Test benches.
- Secondary gauges
- The existing ones in the constructor.

Documentation required:

- Equipment Manufacturer Manuals.
- Manuals of equipment testing and diagnosis.
- Audiovisual means.
- Dossiers to define the procedures and materials to be used.
- Specifications and execution drawings.

3.2.3 Main Functions

Sonafi ME has main functions in manual. The manual is updated based on the TPM concepts. Maintenance functions are divided into 3 types:

1. Production Equipment;
2. Support Equipment;
3. Channels and Form of Communication.

The Main function of **Production Equipment** are:

- Prepare, implement, maintain and update the Preventive Maintenance Schedule and the respective Maintenance Plans.
- Keep the equipment dossier with the manufacturer's manuals, the condition of the equipment since its installation, record of the interventions made and improvements introduced, safety conditions to observe in its operation.

- Keep track of all maintenance interventions of the various types made on the equipment.
- Determination of performances by equipment using the available computer means.
- Improved availability of spare parts through improved stock management and local suppliers.
- Creation of a continuous improvement plan for the equipment.
- Creation of a training / information plan for human resources assigned to maintenance.
- Management of outsourced activities.
- Creation of management indicators on equipment, spare parts and human resources allocated to maintenance.
- Implementation of these indicators.
- Implementation of existing legislation applicable to equipment and installations.

The Main function of **Support Equipment** are:

- Prepare, implement, maintain and update the Preventive Maintenance Schedule and the respective Maintenance Plans.
- Keep the dossier of the equipment with the condition of the equipment since its installation, manuals, record of the interventions made and improvements introduced.
- Keep all types of maintenance performed on the equipment.
- Improved availability of spare parts through improved stock management and local suppliers.
- Creation of a training / information plan for the human resources assigned to the maintenance of support equipment.
- Management of outsourced activities.
- Implementation of existing legislation applicable to equipment and installations.

The Main function of **Channels and Forms of Communication** are:

- Daily meetings in the DME Office, with the ME Director, the Casting and Finishing Maintenance Coordinators, Warehouse Technician, Preventive Maintenance Technician and invited, if necessary or convenient, at this meeting, all current data and information are analyzed, giving origin the minutes with list of problems, causes, measures, responsible and dates of their implementation.
- Participation in the daily 3R Meeting with the Representatives of the various operating departments of the factory, with the objective of analyzing and taking action on recurring problems.
- Weekly meetings with ME technicians, where all current issues are analyzed.

- Whiteboard in the workshop for general information and urgent messages.

3.2.4 Introducing TPM Cultures to SONAFI

Importance and implementation of TPM are presented step by step to all organization starting from top level of management to job floor workers. SONAFI TPM pillars, TPM culture, team work, importance of OEE and benefits of TPM are the major topics covered in presentation. Presenation photography are shown in Figure41 and Figure42.

Figure 41 Presenting the importance and implementation of TPM to workers part-1

Figure 42 Presenting the importance and implementation of TPM to workers part-2

3.2.5 Methods and Measure Analysis of SONAFI

3.2.5.1 Sonafi TPM Pillar1: Predictive and Systematic Maintenance

The method and measure analysis of predictive and systematic maintenance are classified into 5 parts: Objective; Scope; Users; Instructions; Data Analysis Tool.

Objective. The purpose of this instruction is to describe how the Predictive and Systematic Maintenance of equipment's.

Scope. The main scope of this instruction covers all productive equipment and infrastructure.

Users. The main users of this Predictive and Systematic Maintenance are:

- Maintenance of equipment
- Foundry Coordinator
- Coordinators Mechanization
- Warehouse Technician ME
- Preventive Maintenance Technician

Instructions. The major instruction to be followed in Predictive and Systematic Maintenance are:

- The Preventive and Predictive Maintenance is developed having as sources the information existing in the Manuals of the Manufacturers, TTR (Total Time of Repair) analysis.
- Risk Analysis Tools: FMECA, 5 Why, Ishikawa Diagram.

At the end of each year a Preventive and Predictive Maintenance Calendar (manual) is developed and approved. After parameterizing in the MannWinWin generates a Schedule of OTs, for all critical equipment and installations, translated into Plans/ Maintenance Plans. These Plans are the base documents that contain the activities/ tasks to be carried out. According to the planning, these Plans give a PMP Work Order, for its realization the Production Manager is informed of the area of the need for the equipment to be unavailable for the intervention, so that the equipment or an adjustment in the calendar if it is not possible to do so. These Plans are reviewed whenever necessary.

Regular examination of both predictive and systematic maintenance is explained in below, Figure 43, with Planned Preventive Maintenance (PPM).

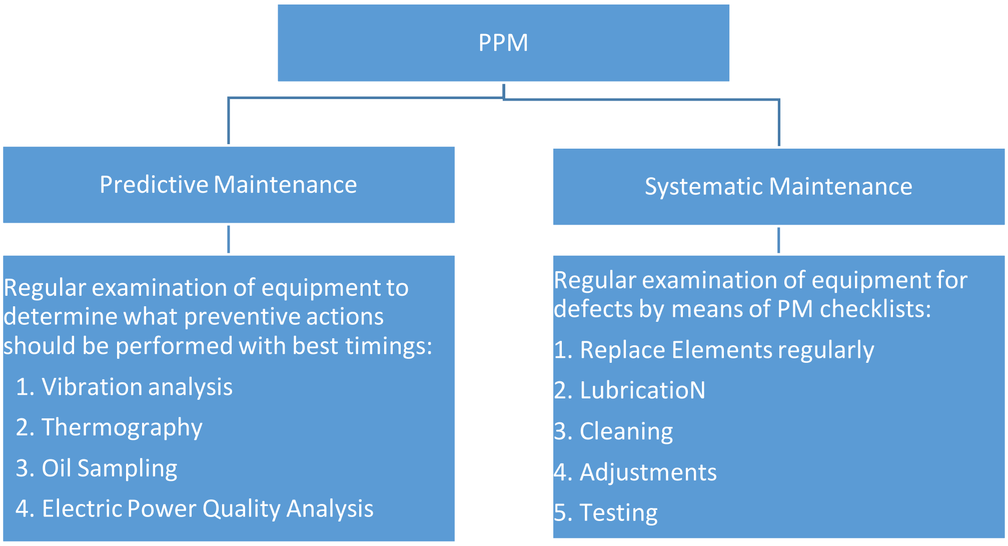


Figure 43 Planned Preventive Maintenance (PPM)

A sample template for predictive and systematic maintenance where the plan is entered manually with description along with time tracking are shown in Figure 44.

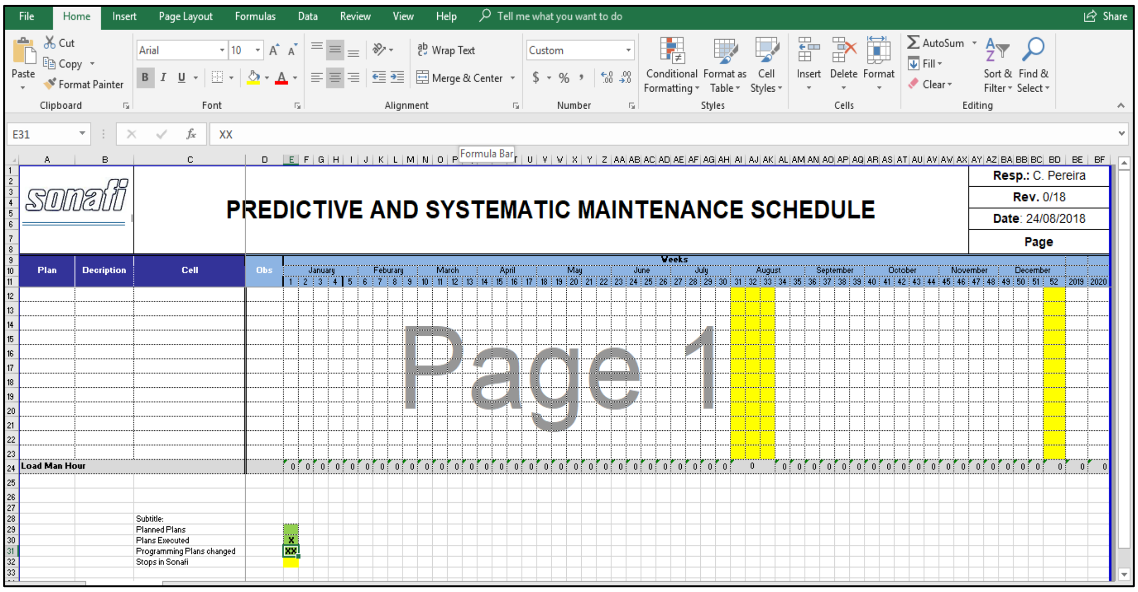


Figure 44 Predictive and Systematic Schedule

Fishbone analysis for low OEE of ME are represented in the form of figure (Figure45). It was indentified 6 cause – Man, Machine, Material, Method – of the low OEE problem.

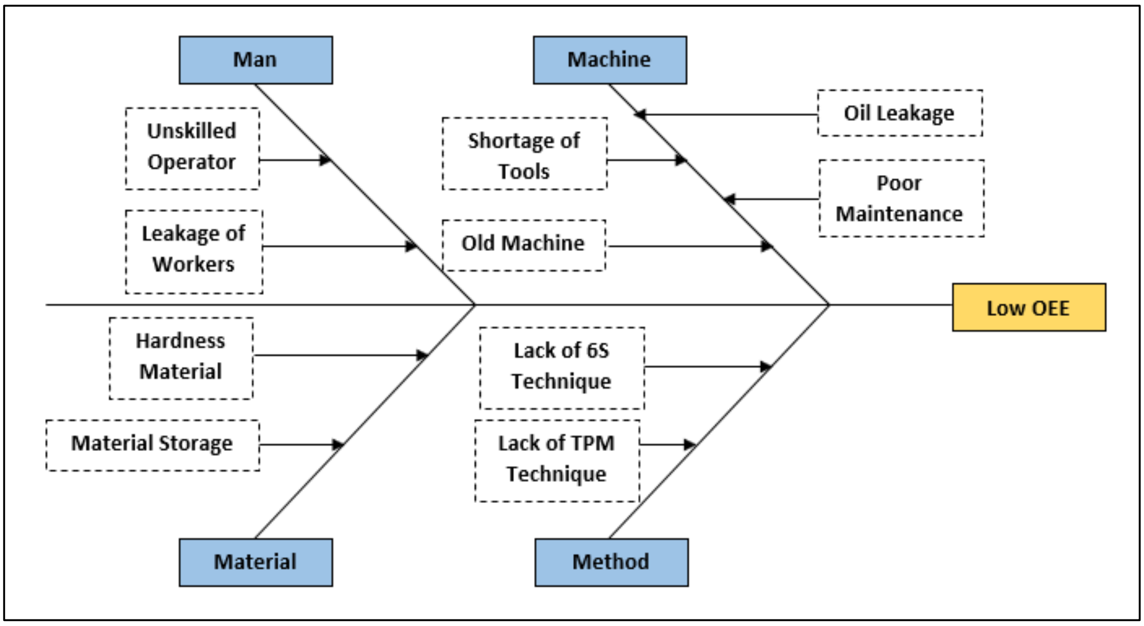


Figure 45 Fishbone Diagram

At the end, the intervention is registered in the Work Order in ManWinWin. This record is attended and after validated by the respective ME Coordinator, and then filed in the database of MannWinWin Sonafi.

3.2.5.2 Sonafi TPM Pillar 2: Curative Maintenance

The method and measure analysis of Curative Maintenance are classified into 5 parts: Objective; Scope; Users; Instructions; Data Analysis Tool.

Objective. The main objectives is how Curative Maintenance is performed.

Scope. The main scope of this instruction covers all productive equipment and infrastructure.

Users. The main users of this Curative Maintenance are:

- Equipment Maintenance
- Team coordinators
- Operators

Instructions. The major instructions to be followed in Curative Maintenance are:

- Healing Maintenance occurs whenever an equipment or installation is unavailable due to a malfunction unpredictable and unexpected.

- Upon detection of a malfunction, the production team coordinator or the operator of the sector where the malfunction occurred.

Data Analysis Tools.

There are several degrees of urgency. The Emergency degree is considered when the equipment/cell stop without production. When the equipment/cell is running in degraded mode is conseidered Urgency degree. The Normal degree is when the equipment/cell is in operation, without loss of production and quality.

The Maintenance Request completed in MannWinWin is automatically sent to the ME technicians box. It is recognized by one of the technicians that is in service, where it analyzes if it can be executed. In case it cannot, it analyzes the same with the issuer. In case of being able to execute, the ME technician verifies if it has the necessary resources for its execution. If there are available resources, the ME technician executes the PM and registers in the maintenance area, among other information: start and end time of the intervention, type of failure, reason and description. In the finish, the PM stays in history in the database of the application ManWinWin. The working Flowchart of curative maintenance are shown in the Figure 46.

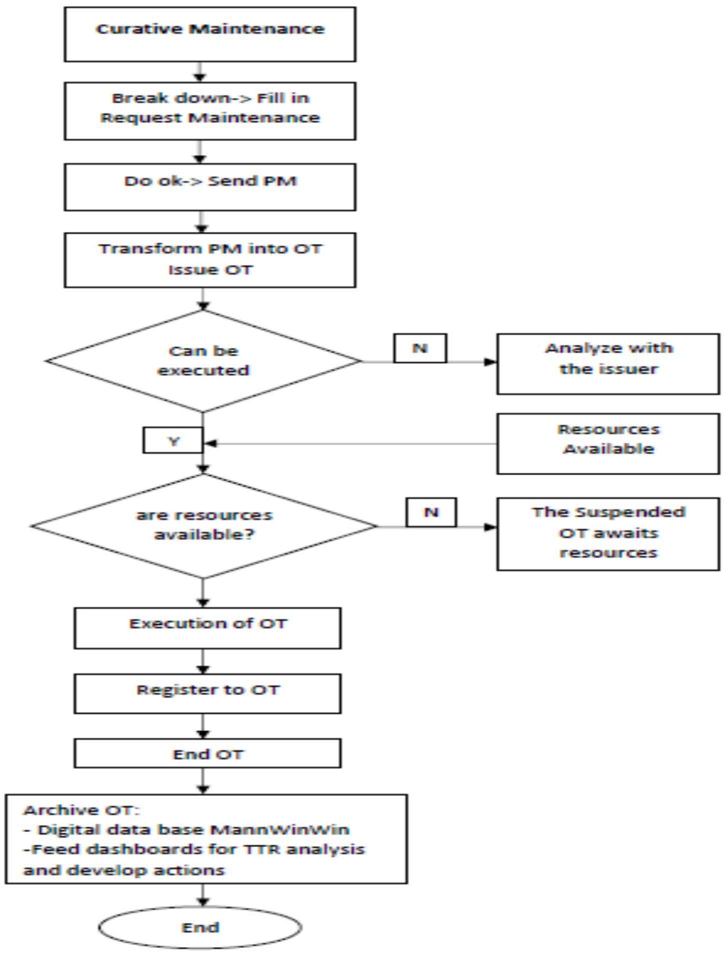


Figure 46 Working Flowchart of Curative Maintenance

3.2.5.3 Sonafi TPM Pillar 3: Continous Improvement

The method and measure analysis of Continous Improvements are classified into 5 parts: Objective; Scope; Users; Instructions; Data Analysis Tool.

Objective. The main objective is know how continuous improvement of equipment is performed.

Scope. The main scope of this instruction covers all productive equipment and infrastructure this instruction.

Users. The main users of this Continous Improvements are: Maintenance Coordinator**;** Production team coordinators**;** Preventive Maintenance Technician**;** Warehouse Technician ME**;** ME technicians.

Instructions. The major instruction to be followed in Continous Improvements are:

- Continuous improvement is one of the company's overall objectives and as such is one of the objectives of the Equipment Maintenance Team, to collaborate, suggest and implement continuous improvement.
- It is the responsibility of the Director and Technical of Preventive Maintenance to analyze the indicators of the equipment namely, MTTR, MTBF, TTR, OEE Availability and the suggestions of the technicians and using quality tools, to promote and to implement actions of Continuous Improvement, in the Plans of Preventive and Predictive Maintenance, either suggested in the Investment Plan, or by immediately implementing improvement actions involving ME technicians and other sectors.
- Whenever the coordinators and/or operators verify possibilities for improvements in equipment, they should alert the Director, Coordinators, MP Technicians and Warehouse and maintenance technicians to jointly analyze the equipment and define an action plan.

Data Analysis Tools. Continous Improvements analysing tools are shown in below (Figure 47). Main action tools used in this work is BE SMART (Figure 48).

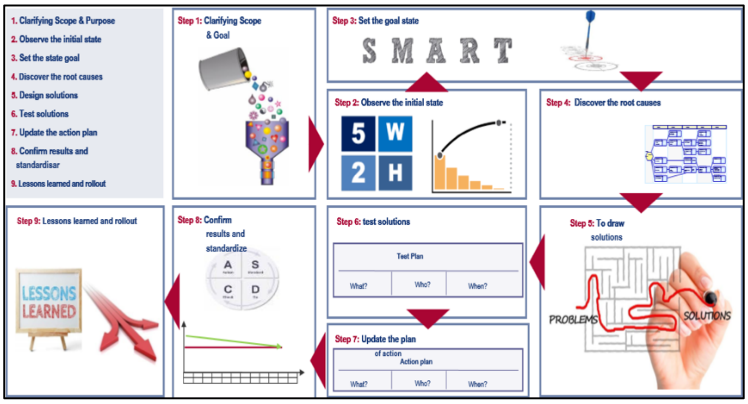


Figure 47 Continous Improvement Analyzing Tool [35]

Figure 48 BE SMART[35]

SMART means: Simple, Measurable, Attainnable, Relevant and Temporal. In Simple field is choosed a specific area for improvement and is defined what is intended exactly. Measurable is the field that establish concrete criteria for measuring progress toward the attainment of each goal set. Assess whether the goal is really acceptable for the team and measuring the effort, time and other costs and compare them with the organization's profits and other priorities are the aims of the feild Attainable. The Relevant field allows to assess the impact of the objective in the organization and to check if the result of the workshop is relevant to the team and to the company's results. Finally, in the Temporal field a goal should be marked in time. At the end in ManWinWin, this data is recorded and after validated by the ME Coordinator. Then kPI's (OEE, MTBF, MTTR) is calculated through ManWinWin.

3.2.5.4 Sonafi TPM Pillar 4: Qualification of Human Resource

The method and measure analysis of Qualification of Human Resources are classified into 4 parts: Objective; Scope; Users; Instructions.

Objective. The main objectives is know how the qualification of the human resources of equipment maintenance is processed.

Scope. All human resources for equipment maintenance are covered by this instruction.

Users. The main users are all human resources for equipment maintenance.

Instructions.

- The qualification of human resources must be a group of skills that all people must have to achieve their best performance based on training.
- On an Average of 15hrs of training allocated to each workers every year.
- Workers are recruited based on their qualification of the required fields.
- Basic training is given in the field of safety&work, Electronics, Machines concerning furnace&foundry, artificial cameras and vacuum system.
- Training are given in topic of Kaizen, IATF16949:2016 to maintenance coordinators.

- The scheduled training of 2018 in buhler on die-casting machines, ABC on robotics, chiron machining equipment's proportion hydraulics and electronics Industrial.

Benefits of Work Based Learning (WBL) are explained to all workers as shown in the Figure 49.

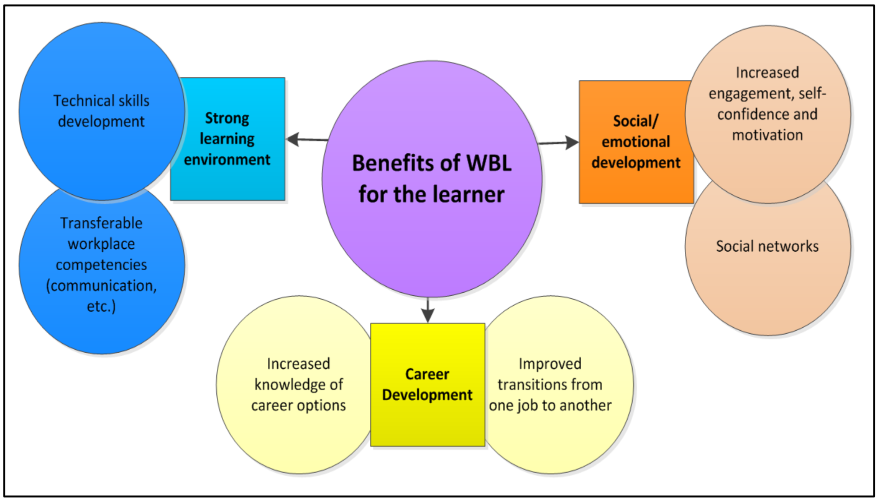


Figure 49 Benefits of WBL [36]

The Diagnosis of training needs is made annually in the first quarter of each calendar year, without prejudice to any situations that may justify, throughout the year, changes to the initially identified needs. The process of diagnosing training needs is based on the following methodology:

1. Every year, each Responsible Person identifies, in the form "Diagnosis of training needs" the need to reinforce certain competencies, taking into account the profile defined for each function and the existing gap in relation to the demonstrated performance.
2. At the same time, when assessing the contractual situation of each employee, some training needs can be identified, which are referred to the HRD through the respective evaluation form;
3. In addition to evaluating the performance of each employee in the scope of the Career Plan, it is also possible to identify certain training needs that are referred to HRD in the performance evaluation form itself ;
4. In addition managers can identify training needs not only in the human resources of their respective teams, but also in other areas, and also record them in the "Training Needs Assessment" form.
5. The diagnosed training needs, translated into training actions to be developed, will be included in the "Annual Training " which, once finished, will be approved by the General Directorate.

Once the training actions to be developed have been approved, it is the responsibility of the HRD to plan and execute them, selecting the training entities, as well as the training model most appropriate to each situation. When the training is carried out internally, the form "Attendance Sheet- " will be completed. Upon completion of the action, the "Professional Training Certificate " will be delivered to the trainees, a copy of which will be filed in the individual process of each employee.

Evaluation of the training action is applicable to all training courses carried out internally by the company, provided that they last for a duration of 4 hours or more. The evaluation of the trainer intends to evaluate the general conditions in which the action took place and is carried out by filling out the trainee of the Training Action Evaluation questionnaire. The assessment of the impact of the training action is applicable only to training courses lasting 20 hours or more. For each internal training action the respective training dossier, which should include the following documents: Attendance Sheet, Evaluation of the training action, Evaluation of the impact of training, is organized.

3.2.5.5 Sonafi TPM Pillar 5: Support System

The method and measure analysis of Support System are classified into 4 parts: Objective; Scope; Users; Instruction; Data Analysis Tools.

Objective. Describe how the equipment support system is handled.

Scope. All equipment of the support system is covered by this instruction.

Users. The main users of Support System are: Total productive maintenance technician ME**,** Team Coordinators and Operators.

Instruction. The major instructions followed in Support Systems are:

- The support system applies TPM activities to continuously improve the efficiency and effectiveness of logistics and administrative functions.
- These logistical and support functions can have a significant impact on the performance of production operations. In line with the vision of a "production system" that includes not only manufacturing but also manufacturing support functions, TPM must the entire embrace enterprise, including administrative and support departments.

The next figure shows the support systems tools that inclued communication, decisoin making and data and document processing.

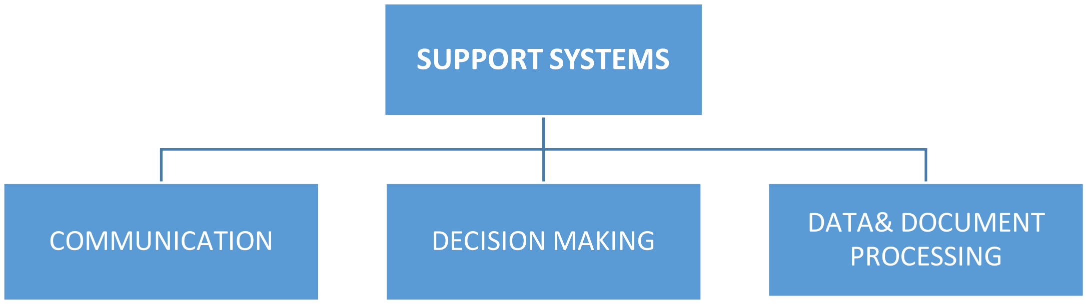


Figure 50 Support Systems Tools

In to respect to communication tool, the communication in the maintenance department of equipment has as main channels:

- Daily meetings in the DME office, with the ME Director, the molding and finishing maintenance coordinators, the warehouse technician, the Preventive Maintenance Technician and the necessary or necessary guests, these meetings analyze all current data and information giving origin the minutes with list of problems, causes, measures, responsible and dates of implementation of the same.
- Participation in the Daily Meeting with the Representatives of the various operational departments of the factory, with the objective of analyzing and taking action on recurring problems.
- Weekly meetings with DME technicians, where all current affairs are analyzed.
- Whiteboard in the workshop for general information and urgent messages.

The chain of decision making follows a hierarchical line of escalation of this:

- The technicians faced with some situation that they cannot solve, and giving rise to the unavailability of critical equipment, must inform their superior, the Coordinator of the area.
- The Coordinators of the areas confronted with any situation that they cannot solve, and giving rise to the unavailability of critical equipment, should inform their superior, the Director.
- The Director in the case of equipment in a situation of unavailability should inform the responsible of the productive area and the Director General.

The equipment maintenance data is stored in the ManWinWin database. The documents are stored in the MS Office and in the Maintenance Warehouse Office.

Document retention follows the Sonafi Quality Manual. All the data about Support Systems are collected in ManWinWin software.

3.2.5.6 Sonafi TPM Pillar 6: Autonomous Maintenance

The method and measure analysis of Autonomous Maintenance are classified into 5 parts: Objective; Scope; Users; Instructions; Data Analysis Tool.

Objective. The main objectives is how Autonomous Maintenance is handled.

Scope. All human resources and all productive equipment are covered by this instruction.

Users. The major users to Autonomous Maintenance are: Preventive Maintenance Technician ME**,** Team coordinators and Operators.

Instruction. The major instructions followed in Autonomous Maintenance are:

- The Autonomous Maintenance is characterized by the responsibility and autonomy of the operators, with the development of their competences.
- In order to be able to carry out their tasks in a structured and clear manner, a 1st level maintenance instruction has been created. This is a special case of preventive maintenance and consists of an action plan which is carried out by the equipment operators in accordance with the specified in the 1st Level Maintenance Work Instructions.
- To ensure proper use of the 1st Level Maintenance Work Instructions, the Maintenance Technician.
- preventive ME is responsible for giving and keeping up-to-date the training of Team Coordinators and they are responsible for giving and guaranteeing training to operators.

Equipment Maintenance prepares the 1st level instructions, its general code is ME the support registers follow the general code it makes them available to the coordinators of the casting/finishes in charge of the sector where they will be used. During the shift, the casting/finishing operator has to perform the tasks defined in the 1st Level instruction and proceed to the correct completion of the respective Registration to the symbology defined in the Instruction. The casting/finishing team coordinator verifies that all operators have filled in the Register(s).

The casting/finishing team coordinator analyzes the sheets taking into account to the state of the equipment and one of the following three situations may occur:

- Everything is OK with the equipment, the records are stored in the file of the workstation

- An equipment intervention is required, the casting/finishing coordinator makes a Maintenance Request for maintenance of equipment through the ManWinWin - Maintenance Order application.
- Operation in degraded mode, the sheet is stored in the file of the respective equipment and is analyzed in the next intervention that is requested for the equipment.
- The maintenance technicians of shift equipment receive the Maintenance Requests and according to priorities and load analyzes and performs an intervention on the equipment.
- The records are filed in the cabinet of the foundry/finishers.

Maintenance Audit is performed as follows:

1. An audit is performed monthly by the Preventive Maintenance Technician, responsible for the area and operator to at least 2 cells/equipment of each operational area Finishing and Casting.
2. A 1st Level Maintenance Audit Check List generated by ManWinWin is used.
3. The deviations shall be recorded in field 007, the measures to be taken registered and controlled until completion by the Preventive Maintenance Technician.

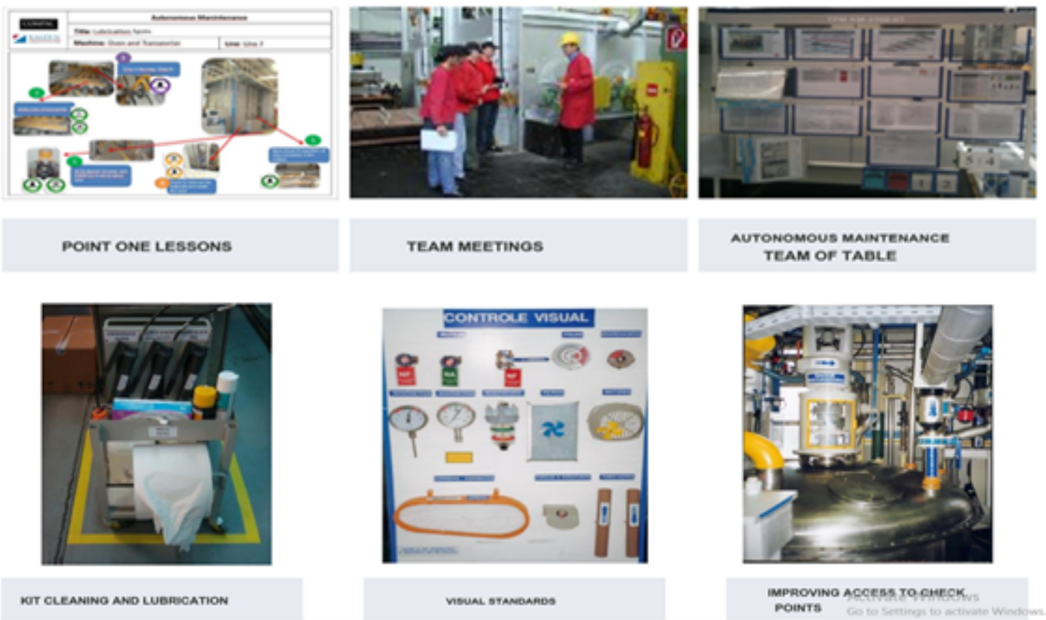


Figure 51 Autonomous Maintenance Tools[35]

The above two figure represents the autonomous Maintenace tools like,

- Point One Lesson
- Team Meeting
- Team of Table
- Kit Cleaning and Lubrification
- Visual Standards
- ImprovingAccess to check area

The Flowchart of working of Autonomous Pillars are shown below in the Figure52:

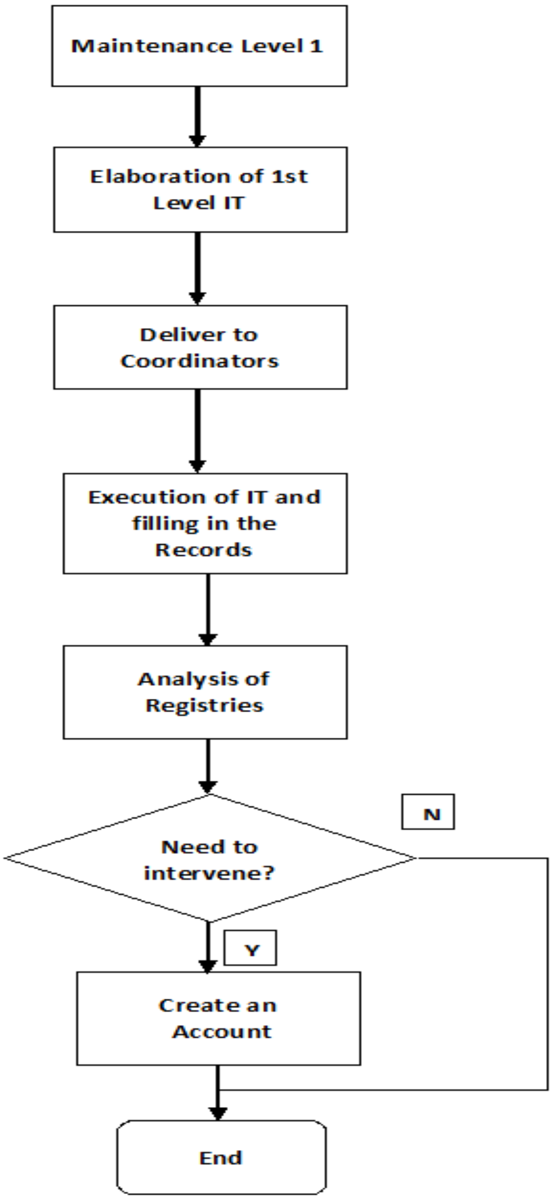


Figure 52 Working Flowchart of Autonomous Maintenance Tools

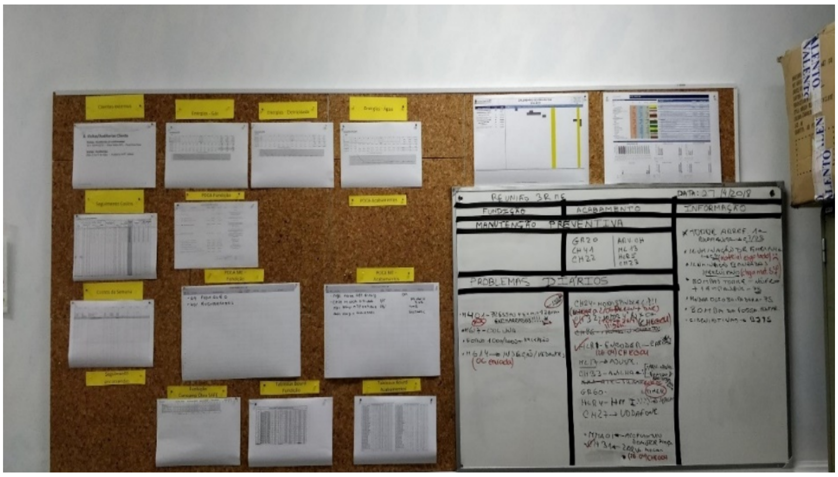


Figure 53 Tabular Board of Team of Table ME with unique colour

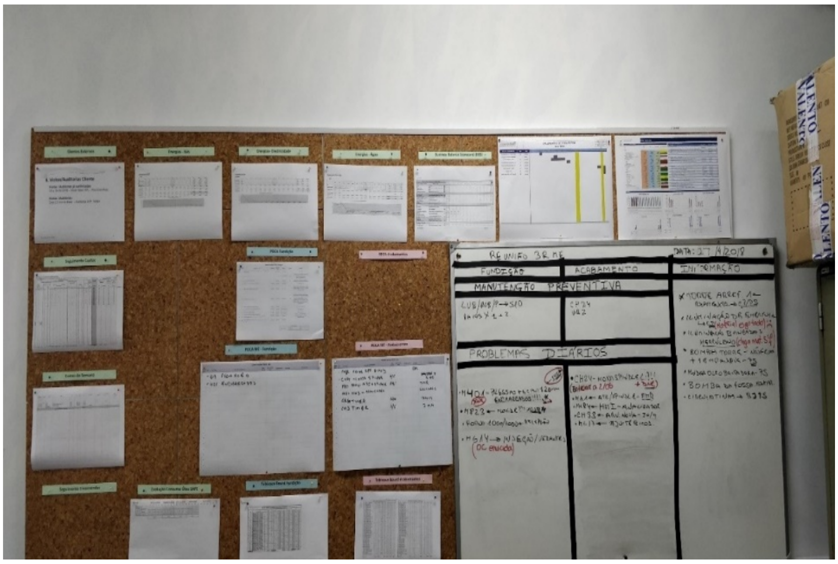


Figure 54 Tabular Board of Team of Table with different colour for different department in ME

The above 2 figureS represents the Tabular Board of Team of Table with unique colour and different colour for different departments like foundry, finishing area and Warehouse & SpareParts.The day today Problems are noted and written in Respective fields along with A3 ME of SONAFI.

Data Analysis Tools: All the data about Autonomous Maintenance are collected in ManWinWin Software.

3.2.5.7 Sonafi TPM Pillar 7: Supplier Maintenance

The method and measure analysis of Supplier Maintenance are classified into 5 parts: Objective; Scope; Users; Instructions; Data Analysis Tool.

Objective. Describe how the purchase equipment maintenance services and materials occurs.

Scope. This instruction applies to all subcontracted maintenance services (including equipment and infrastructures) and purchase of materials for equipment maintenance.

Users. The main users of Supplier maintenance are: ME Director**,** Coordinators ME**,** Warehouse Technician ME and Preventive Maintenance Technician.

Instruction. The major instructions to be followed under supplier maintenance are:

- Where subcontracting of a maintenance or material list of approved suppliers, if they are critical.
- The list of authorized suppliers has been carried out and is reviewed annually, results from the market.
- analysis of the previous year's shopping list and the result of the annual evaluations.
- After consultation of this document, the person responsible for the sector or someone appointed by him or her shall the budget request of the service or predicted material. The budget request has to be
- carried out by at least 2 suppliers.
- Where there is knowledge of other undertakings having the potential to supply and not be on the list of suppliers, an alternative proposal should also be requested and after consultation responsible for the sector to include it in the list of authorized suppliers
- After an analysis of the budgets received considering the implementation timings and the price, the sector manager should request the approval of his hierarchical superior.

Data Analysis Tools: All the data about Supplier Maintenance are collected in ManWinWin Software based on Purchased order.

3.2.6 Implementation of 6S along with TPM in SONAFI

6S is a process for creating and maintaining an organized, clean, and high performance work place, which serves as a foundation for continuous improvement activities [37].

The Six “S” are: Sort; Set in order; Shine; Standardize; Sustain; Safety – Security (Figure 55)

Figure 55 Lean-6S [39]

6S is the system to identify and establish the follow things [38]:

1. Identify waste;
2. Identify opportunities for improvement;
3. Establish an efficient flow of activities and materials;
4. Keep the organization focused on business objectives;
5. Maintain improvement.

The 6S aims to create an environment that is [38]:

1. Self-explanatory;
2. Self-regulator;
3. Self-Improvement.

6S majorly promotes the following [38]:

1. Reduction of value activities not added;
2. Reduce employee and supplier errors;
3. Reduction of orientation time and training of employees;
4. Reduced search time for tools, parts, supplies, information, etc;
5. Reduce inventory of tools, parts, materials and associated costs.

The major benefits of 6S are [38]:

1. Creating a safe and enjoyable workspace;
2. Increased quality of work;
3. Reduction of costs;
4. Increased customer satisfaction;

5. The focus of 6S is on the working process in executing in the area of work of the people.

3.2.6.1 6S Road Map

The 6s road map has 3-phases [38].

3.2.6.1.1 Phase 1

Phase 1 represents the preparation of the event 6S [38]. This include know customer expectations, draw the charter, train the team that uses the worplace and logistics/planing.

3.2.6.1.2 Phase 2 - Beginning 6S

The phase 2 represents the making of the event 6S [38] and include: build the team, prepare the team and fact-findind (observe, identify situations of waste, draw the physical space of the workplace with the process flow, etc).

1º S: SORT – SEPARATE

The 1º S goal is maintain in the work area what is strictly necessary in order to:

1. Stream the process;
2. Eliminate mistakes (exchanges of materials, information, etc.);
3. Reduce Inventory;
4. Separate what is needed from what is not needed;
5. Create a method to keep the area free from unnecessary items.

The main task consists in the evaluation of the entire work area, removal all tools, materials, equipment unecessary. Only what is considered essential should be maintained. Materials should be separated with discretion. They should even be labeled. They can be useful in other areas of the company and therefore useful. It is common for companies to have an area where these materials are placed and inventoried. The organization is then made aware of its existence and available for use. The criteria are defined taking into the account of the frequency of use.

The activities to develop:

1. Remove photos from before;
2. Review separation criteria;
3. Create an area for the materials to be removed from the intervention site;
4. Set time for the 1st S;
5. Remove what can be removed;
6. Create a procedure that ensures that in the future there will not be adequate storage (create space with specific rules of use);

7. Remove the tagged items;
8. List the items removed for submission to departments;
9. Take photos after the 1st S.

2º S: SHINE – CLEAR

The main goals of Shine are [38]:

1. Promoting a comfortable and safe workplace;
2. Enable high visibility and reduce search times;
3. Ensure a higher quality of work;
4. Increase equipment life;
5. Decrease the Down Time of equipment (cleaning while inspection process).

The main steps followed in this S are:

1. Decide what to clean (inspect), when and how;
2. Decide which method of cleaning/inspection;
3. Use preventative measures to keep it clean;
4. Create checklists.

3º S: SET IN ORDER - ORGANIZE and 4º S - SAFETY – SECURITY

In the 3rd and 4th S the team analyzes the work area with support in the information already collected in the experiences obtained during the 1st and 2nd S. The aim is now to reduce sources of waste and errors and to transform the intervention site into a space managed by a visual management. These two S has the following focuses [38]:

1. Infrastructure, equipment and tools (focus on the organization taking into the account that defined flow and the labeling and markings of the equipment and structure (floor, walls, etc.)
2. Identify and label hot, cold, steam, compressed air, electrical systems, to simplify the search for lines and avoid accidents).
3. Operators' tools must be organized, marked, labeled and close to the place of use in order to reduce movement and waiting.
4. Manometers and indicators must be marked so that anomalous situations can be detected "in the blink of an eye" (work zones, calibration or verification conditions, etc.)
5. Infrastructures and ground must be marked as the area of passage of people, goods, inventory, tools, buffer zones, rejected materials and safety zones.

In to respect to the Safety, the focus is on people's alert to potential danger situations and control actions that prevent situations of lack of safety. Hazard statements and safety instructions should be placed where necessary. Distinguish between first aid zones, fire extinguishers, special machinery protection devices, etc.

With regard to the inventory, the focus is on Identifying materials, organizing storage areas, transporting materials, type of material, maximum/minimum quantities and location.

The activities to develop:

1. Take photos of before;
2. Plan what to do and do what is planned, involve people in the place of intervention, maintenance, safety, engineering, quality, etc;
3. Use standardized colors for markings;
4. Use photographs, charts, and diagrams for ease of recognition and instructions.
5. Properly maintain the first 3 S as a habit;
6. Ensure that employees who use the work area know their operation and the established rules;

5º S: STANDARDIZATION

The objective of 5º S is to establish a set of good practices and ensure that all team members comply with them, standardiziying the following [22]:

- The physical space of the work area;
- The wipe, the process flow;
- The sequence of work;
- Materials and tools used;
- Process machines and parameters;
- Quality parameters, methods of measurement and communication.

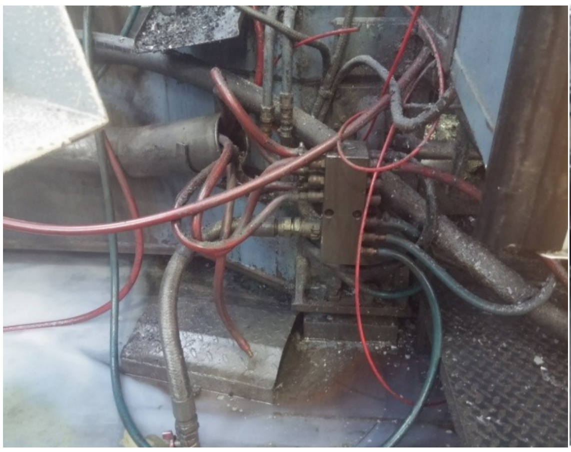
6º S: SUSTAIN (AUTO DISCIPLINE)

Sustain is the 6th "S" in Lean "6S". The Sustain actions are taken below in Sonafi they are divided into 2 parts: goal e necessary conditions. The main goal is to maintain the momentum generated in the improvement process. The necessary conditions are: consistency (necessary understanding of 6S) and 5S Audit (student/leader ffollower).

3.2.6.1.3 Phase 3

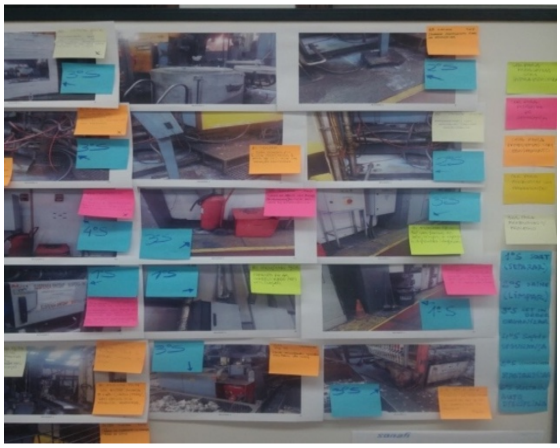
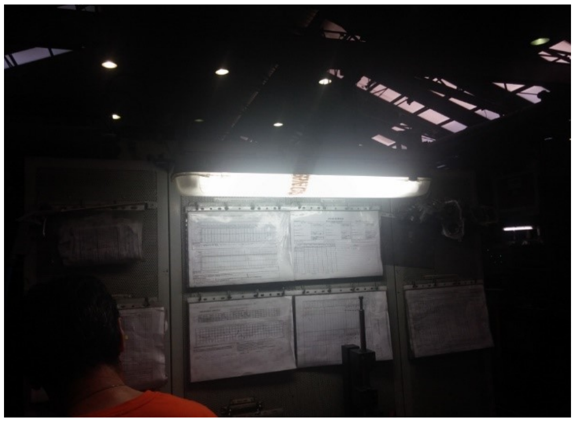
Phase 3 follow implementation to ensure sustainability. All the daily data including inspection, monitoring and comments from the first 2 phases are noted manually then added to Manwinwin software. In Table 7 shows the results of before and after implementation of 6S in SONAFI. In Table 8 shows the planning and execution each stage of 6S in SONAFI.

Table 7 Before and After Implementation of 6S

Before implementation of 6S	After implementation of 6S
	
	
	


LIGA BRANCA

Table 8 Planning and Executing of 6S

Planning and executing of 6S	
	
	

3.2.7 IATF 16949:2016

IATF 16949:2016 was jointly developed by the International Automotive Task Force (IATF) members and submitted to the International Organization for Standardization (ISO) for approval and publication [40]. The document is a common automotive quality system requirement based on ISO 9001 and customer specific requirements from the automotive sector.

IATF 16949:2016 emphasizes the development of a process-oriented quality management system that provides for [40]:

1. Continual improvement;
2. Defect prevention and reduction of variation;
3. Waste in the supplyi.

The goal is to meet customer requirements efficiently and effectively.

3.2.7.1 IATF 16949:2016 of SONAFI:

The IATF 16949:2016 of Topics, Clauses with Headings and Comments are shown below in Table 9. These clauses are mandatory clauses for automotive industry it is finialized after discussion with ME-Coordinators [41].

Table 9 Topics and Clauses of IATF 16949:2016 for Sonafi[41]

TOPICS	IATF 16949:2016	HEADINGS	COMMENTS
Planning	6.1.2.1	Risk analysis	The need to identify, analyze, and consider actual and potential risks was already covered in various areas of ISO/TS 16949. The IATF adopted the additional requirements for risk analysis, recognizing the continual need to analyze and respond to risk and to have organizations consider specific risks associated with the automotive industry.
Support	7.1.3.1	Plant,facility, and equipment planning	Increased focus on risk identificatio and risk mitigation, evaluating manufacturing feasibility, re-evaluation of changes in processes, and inclusion of on-site supplier activities.
	7.5.3.2.1	Record retention	Requires a record retention process that is defined and documented ad that includes the organization's record retention requirements.
Operation	8.3.5.2		Strengthened verification requirements, process input

		Manufacturing process design output	variables, capacity analysis, maintenance plans and correction of process non-conformities.
	8.4.1.2	Supplier selection process	Assessment used to select suppliers needs to be extended beyond typical QMS audits.
	8.5.1.2	Standardized work – operator instructions and visual standard	The requirements for standardized work, including the requirement to address specific language needs.
	8.5.1.5	Total productive maintenance (TPM)	The requirement for equipment maintenance and overall proactive management.
Improvement	10.3.1	Continual improvement supplemental	Use of TPM, Lean, Six Sigma, and other manufacturing excellence programs.

Planning:

- **Section 6.1.2.1: Risk analysis** [41]

The need to identify, analyze, and consider actual and potential risks was over in various areas of ISO/TS 16949.The IATF adopted additional requirements for risk analysis recognizing the continual need to analyze and respond to risk and to have suppliers/organizations consider specific risks associated with the automotive industry. Organizations would need to periodically review lessons learned from product recalls, product audits, field returns and repairs, complaints, scrap, and rework, and implement action plans in light of these lessons. The effectiveness of these actions should be evaluated, and actions integrated in to the organization's QMS.

Support:

- **Section 7.1.3.1: Plant, facility, and equipment planning** [41]

This updated section includes an increased focus on risk identification and risk mitigation, evaluating manufacturing feasibility, re-evaluation of changes in processes, and inclusion of on-site supplier activities. Many operational risks can be avoided by applying risk-based thinking during planning activities, which also extends to optimization of material flow and use of floor space to control non-conforming product. Capacity planning evaluation during manufacturing feasibility assessments must consider customer-contracted production rates and volumes, not only current order levels. Capacity should be re-evaluated for any process changes.

- **Section 7.5.3.2.1: Record retention** [41]

This section now requires a record retention process that is defined and documented, and that includes the organization’s record retention requirements. Specifically calls out production part approvals, tooling records, product and process design records,purchase orders, and contracts/amendments. If there is no customer or regulatory agency retention period requirements for these types of records, “the length of time that the product is active for production and service requirements, plus one calendar year” applies.

Operation:

- **Section 8.3.5.2: Manufacturing process design output** [41]

Changes in this section strengthened verification requirements, process input variables, capacity analysis, maintenance plans and correction of process nonconformities. It clarifies that the process approach methodology of verifying outputs against inputs applies to the manufacturing design process. The list of manufacturing design outputs is also expanded.

- **Section 8.4.1.2: Supplier selection process** [41]

While ISO/TS 16949:2009 did address supplier selection in the ISO 9001:2008 boxed text via the Purchasing Process, the supplier selection process was not as detailed. This section now specifically calls out supplier selection process criteria, in addition to clarifying that it is a full process. The assessment used to select suppliers needs to be extended beyond typical QMS audits and include aspects such as: risk to product conformity and uninterrupted supply of the organization’s product to their customers, etc. This process will need to be followed for new suppliers.

- **Section 8.5.1.2: Standardized work – operator instructions and visual standards** [41]

Through this section, IATF 16949 strengthens the requirements for standardized work, including the requirement to address specific language needs. Standardized work documents need to be clearly understood by the organization’s operators and should include all applicable quality, safety, and other aspects necessary to consistently perform each manufacturing operation.

- **Section 8.5.1.5: Total productive maintenance** [41]

Strengthens the requirement for equipment maintenance and overall proactive management of the Total Productive Maintenance (TPM).TPM is a system for maintaining and improving the integrity of production and quality systems through machines, equipment, processes, and employees that add value to the manufacturing process. TPM should be fully integrated within the manufacturing processes and any necessary support processes. Metrics need to be more than on time completion of PM's and these are inputs into Management Review. Documented maintenance objectives including but not limited to OEE (Overall Equipment Effectiveness), MTBF (Mean Time Between Failure), and MTTR (Mean Time To Repair), which shall form an input into management review .Regular review of maintenance plan and objectives and a documented action plan to address corrective actions where objectives are not achieved. Use of planned preventive maintenance methods, e.g. periodic inspection without disassembling the equipment, visual checks, cleaning and some servicing, and replacement of parts, in order to prevent sudden failures and process problem. Use of predictive maintenance methods, as applicable e.g. non-destructive testing (oil analysis, vibration analysis, thermal imaging, and ultrasonic detection). Periodic overhaul, where the equipment is periodically stripped down, inspected, and overhauled at fixed intervals and any parts found below standard are repaired or replaced.

Performance Evaluation

- **Section 9.3.3.1: Management review outputs – supplemental** [41]

Enhanced section ensures action is taken where customer requirements are not achieved and supports the continual analysis of process performance and risk. Even though process owners should address customer performance issues related to the processes they manage, this requirement gives top management the clear and ultimate responsibility to address customer performance issues and ensure the effectiveness of corrective actions.

Improvements

- **Section 10.3.1: Continual improvement – supplemental** [41]

It changes in this section clarify the minimum process requirements for continual improvement: identification of methods, information and data; an improvement action plan that reduces variation and waste; and risk analysis (such as FMEA). Use of TPM, Lean, Six Sigma, and other manufacturing excellence programs or methodologies should follow a structured approach that continuously identifies and addresses opportunities for improvement.

Finnaly, after IATF 16949:2016 clauses of SONAFI is finalized and made into manual. SONAFI IATF 16949:2016 manual went to various audits in the intern period. It was acheived certification in Quality Management System Audit IATF 16949:2016 performed by Bureau Veritas and also by several main Sonafi customers audits in the company like Porche, Groupe Renault France, Valeo, Borg Warner, Renault Nissan, VW, DGH-Group.

3.2.8 Benefits and Challenges in Implementation of TPM

Operational improvements resulting from successful TPM implementation and their benefits are presented in Figure 56:

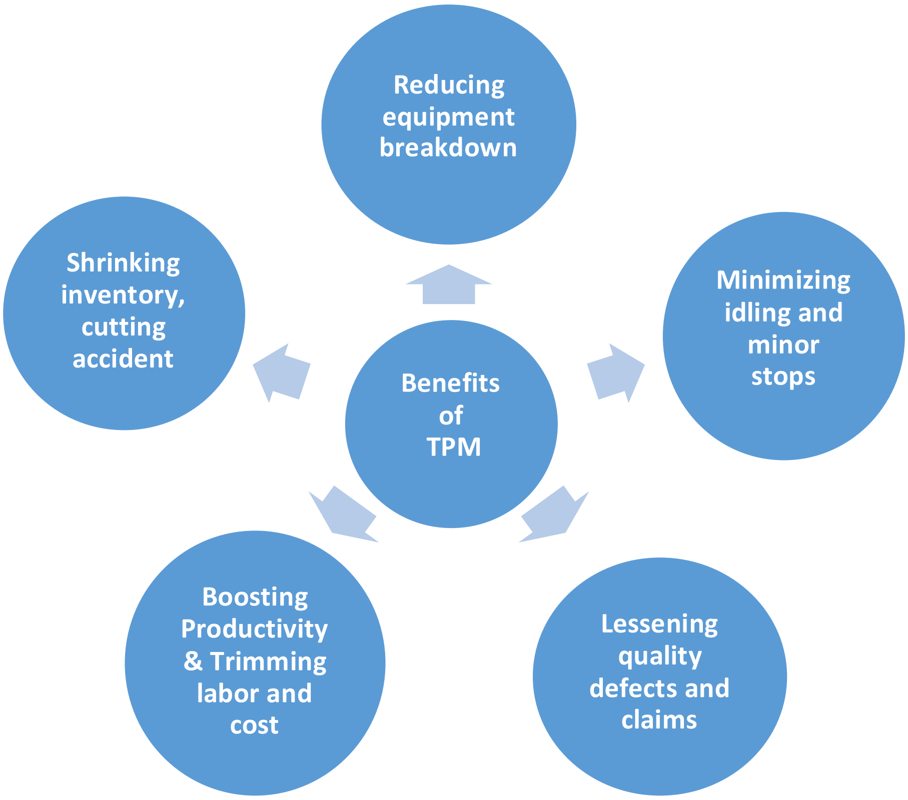


Figure 56 Benefits of TPM

The direct benefits of TPM are:

1. Increase in productivity and overall plant efficiency by 1.5 or 2 times;
2. Customer complaints are rectified swiftly;
3. Manufacturing cost is reduced considerably by up to 30%;
4. As the right quantity in the required quality is delivered to customer at the right time, their needs are satisfied by 100%;
5. Accidents are reduced considerably;
6. Decrease in pollution levels by following pollution control measures.

The Indirect benefits of TPM are:

1. Total productive Management ensures higher confidence level among the employees;

2. Better upkeep of the work place by making it clean, neat and attractive;
3. Favorable change in the attitude of the operators;
4. TPM helps to achieve the preset goals by working as group;
5. Horizontal deployment of a new concept in all areas of the organization;
6. Sharing of knowledge and experience;
7. Obtaining of a feeling of owning the machine by the workers.

Elliot presents eleven general challenges and barriers to achieving manufacturing excellence that might well summarize many of the barriers to successful TPM implementation. As expected, many of the barriers align closely with the success factors for successful TPM implementation; that is to say, successful implementers leverage the success factors to overcome the obstacles and barriers [5].

1. **Underestimating the task.** ”Excellence requires a total commitment to process capability, variation reduction, and creation of a benchmark employee knowledge base.”
2. **Lack of management consensus.**
3. **Underestimating the importance of knowledge.** ”Often, managers believe that the only missing performance ingredient is effort.” Documenting and proliferating knowledge and learning was discussed in the previous section on success criteria for TPM implementation.
4. **Complexity strangles performance.** Complexity “is the single greatest deterrent to performance excellence”. Following a proven standard implementation strategy and process reduces the complexity and the unknown.
5. **Inconsistent and unclear expectations.**
   a) Objectives that create organizational conflicts.
   b) The use of generalized or concept objectives without specific, measurable, activity-driven performance goals.
6. **The challenge of passion.** ”Excellence is the most difficult of all business or personal objectives to define and achieve. It requires an uncompromising passion to excel.” Note the consistency with Nakajima’s passion for zero fail/zero-quality loss/zero-accident.
7. **Staffs that take charge.** Staff objectives not consistent and aligned with organizational performance goals.
8. **Neglecting the basics.** ”Without a focused organizational commitment to the basics of variation reduction, service, cost, and safety, there is no foundation on which to build a successful strategic plan.”
9. **Resistance to daily discipline.**
10. **Limited involvement experience.**
11. **Too much focus on output measures rather than the quality of the process input.**

3.3 Data Analysis

3.3.1 Methods to Measure Analysis of Pillars-ManWinWin

The ManWinWin (logo in Figure 57) - Industrial & Infrastructure Maintenance Management – is a software with the key features [40]:

- Equipment fleet management, data sheets and documents;
- Preventive maintenance management;
- Automatic calendar scheduling with drag and drop scheduling;
- Maintenance requests (operators) serviced with corrective work orders;
- Complete maintenance history (by equipment, production line, cost center, etc.);
- User-customized analysis, reporting and maintenance indicators (MTTR, MTBF, MWT) and KPI;
- Stock management with alerts;
- Mobile access for quick logs.

Figure 57 Logo of ManWinWin Software[40]

ManWinWin allows maintenance managers to [40]:

- Save a lot of time in quick access to all the information of the equipment of the installation: datasheets, documentation, planned works, history of maintenance, applied parts, etc;
- Plan maintenance interventions in a timely manner and thus increase the availability of equipment and the productivity of maintenance teams;
- Build maintenance history and make better technical decisions that reduce costs and increase the efficiency of production equipment;
- To plan in a timely manner the necessary parts for the maintenance, guaranteeing their availability in stock and with automatic alerts for the need of purchase, avoiding delays due to stock rupture;
- Implement a maintenance system that complies with the maintenance requirements required by law and international certifications (ISO, IFS, OHSAS, BRC, cGMP).

Figure 58 ManWinWin-Improving Maintenance [40]

With Manwinwin software is possible to collect data for all the Pillars of TPM as mentioned above and also data are entered in excel file manually as well. It is used to find user-customized analysis, reporting and maintenance indicators (MTTR, MTBF, MWT) and KPI.

3.3.2 Data Analysis using OEE KPI

Key performance Indicators (KPIs) are variables that organizations use to assess, analyze and track manufacturing processes. These performance measurements are commonly used to evaluate success in relation to goals and objectives.The KPIs selected to describe the work place are OEE.

OEE is the ratio of Fully Productive Time to Planned Production Time. The nature of this calculation makes achieving a high OEE score quite challenging. In practice, the generally accepted world-class goals for each factor are quite different from each other, as is shown in the image below. Note that these figures apply to discrete manufacturing (as opposed to process industries) [42].

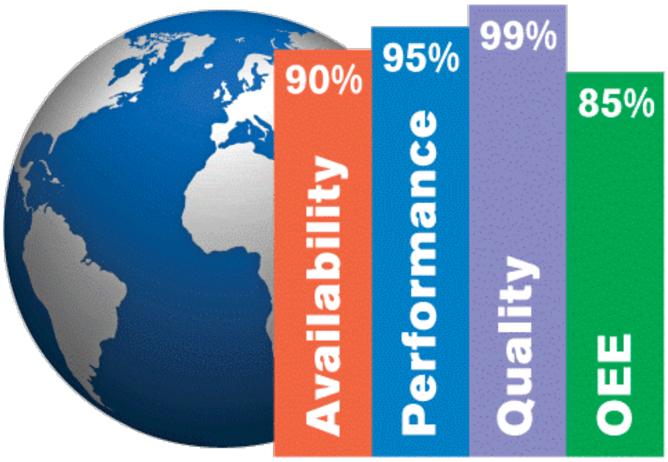


Figure 59 World Class OEE[43]

It is often thought that a World-Class OEE score is 85% (Figure 59). The companies should not fixed in this value of OEE as the target, but instead fixate on the ability to improve the value of OEE [43].

3.3.3 OEE Calculations

OEE is the ratio of fully productive time to planned production time. In practice it is calculated as [44]:

OEE = Availability x Performance x Quality →(2)

If you substitute in the equations for availability, performance and quality, and then reduce them to their simplest terms, the result is:

OEE = Good Pieces x Ideal Cycle Time/Planned Production Time →(1)

This is also an entirely correct way to calculate OEE, and with a bit of reflection you will realize that multiplying Good Pieces by Ideal Cycle Time results in Fully Productive Time (producing only good pieces, as fast as possible, with no down time).

In practice, availability, performance, quality and OEE are calculated from production data gathered from your manufacturing process [44].

Availability is the ratio of operating time (which is simply planned production time less down time) to planned production time, and accounts for down time loss. It is calculated as [44]:

Availability = Operating Time/Planned Production Time →(3)

Performance is the ratio of net operating time to operating time, and accounts for speed loss. In practice it is calculated as: Performance = (ideal cycle time x total pieces)/operating time ideal cycle time is the minimum cycle time that your process can be expected to achieve under optimal conditions, for a given part. Therefore, when it is multiplied by total pieces the result is net operating time. Ideal cycle time is sometimes called design cycle time, theoretical cycle time or nameplate capacity. Since, rate is the reciprocal of cycle time, performance can also be calculated as [44]:

Performance = (Total Pieces/Operating Time)/Ideal Run Rate →(4)

Quality is the ratio of fully productive time (time for good pieces) to net operating time (time for total pieces). In practice it is calculated as [44]:

Quality = Good Pieces / Total Pieces →(5)

As refered previousely, there are several facility maintenance metrics. The Mean Time Between Failures (MTBF) is the average time between each failure. Some of the variables to iron out before applying is the definition for "uptime". A machine running at a fraction of its intended performance is likely not acceptable to be considered "uptime". Whatever decision is made, that it is applied consistently across all pieces of equipment [44]**.**

MTBF=Total Uptime/Number of failures →(6)

Note that, there are some items that are not repairable, but they are replaced. Such examples are light bulbs, switches, torn belts. In such cases, the term Mean Time to Failure (MTTF) is used. There is also the debate of planned downtime. Robust TPM programs have planned downtime for maintenance and predictive tools may create planned replacements or repairs in effort to reduce unplanned downtime and variability in uptime performance. Ideally, the higher the MTBF the better. However, it is likely to plateau at a certain point due to planned downtime and intended maintenance. Then the challenge becomes how to reduce the planned outages and get better life out of the components or items involved so these planned intervals can be expanded.

The Mean Time to Repair (MTTR) is the average time to repair something after a failure. As above, it is important to clarify what exactly constitutes a failure and downtime vs uptime. "Uptime" at a significantly compromised rate of production due to poor maintenance is usually not acceptable. Allowing this to continue can show a better MTBF than the story in its entirety should show [43].

MTTR=Total Downtime/Number of failures →(7)

The MTTR puts an emphasis on Predictive and Preventive Maintenance. Better preparation, spare parts programs, predictive analysis, are methods to reduce the MTTR. Not all repairs are equal. The following equation illustrates the relations of MTBF and MTTR with availability [45]

Availability = MTBF/(MTBF+MTTR) →(8)

The following conclusions can be reached based on these formulas:

1. The higher the MTBF value is, the higher the reliability and availability of the system.
2. MTTR affects availability. This means if it takes a long time to recover a system from a failure, the system is going to have a low availability.
3. High availability can be achieved if MTBF is very large compared to MTTR.

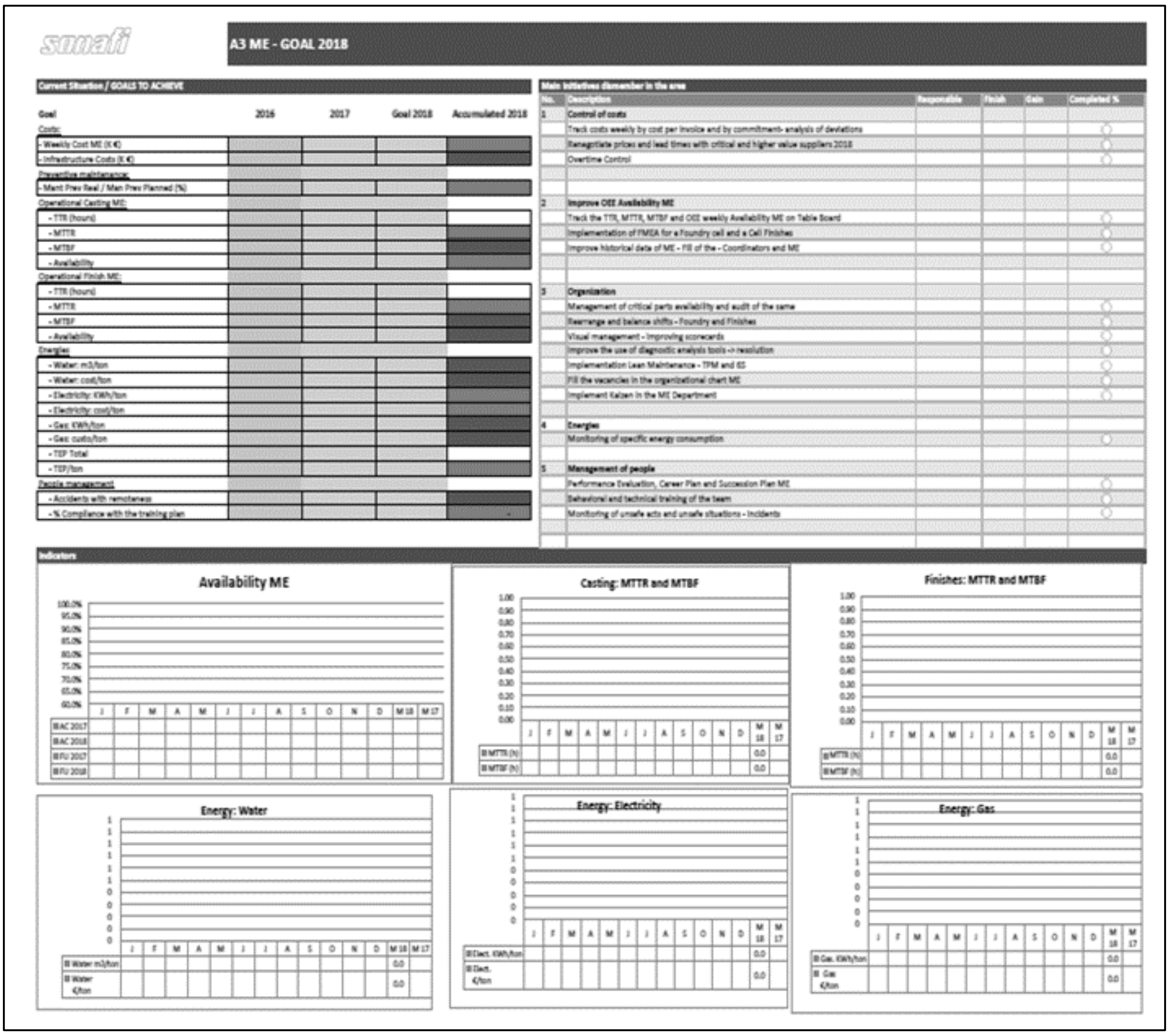


Figure 60 A3 ME- Template of SONAFI

Figure 60, divided in Figure 61, Figure 62, Figure 63, Figure 64 and Figure 65 is the A3 Template of SONAFI to measure the current situation and goals to acheive in a calender year. The values are manually entered to calculate and analysis the availability of OEE, MTBF and MTTR of foundry and finish goods in maintenance Department. It also have tabular column which shows the main initiatives columns along with description, who is responsible of the initivates along with completion date and completed percentage are mentioned. Along with this data we can also compare the past year results with our current value to note the changes in value with graph representation as well. The below 5 figures represent the current value/goals to acheive (Figure 61), main Inititaive along with description in ME (Figure 62). Figure 63 compare the availability ME of foundry and finishing area of current year and last year. Figure 64 compare the Die-Casting ME of MTTR and MTBF respectively in chart form. Figure 65 compare the finishing area of ME of MTTR and MTBF respectively in chart. Along with this we can also find the data of cost, energies and people management in A3 ME.

A3 ME - GOAL 2018

Current Situation / GOALS TO ACHIEVE

Goal	2016	2017	Goal 2018	Accumulated 2018
Costs:				
- Weekly Cost ME (K €)				
- Infrastructure Costs (K €)				
Preventive maintenance:				
- Mant Prev Real / Man Prev Planned (%)				
Operational Casting ME:				
- TTR (hours)				
- MTTR				
- MTBF				
- Availability				
Operational Finish ME:				
- TTR (hours)				
- MTTR				
- MTBF				
- Availability				
Energies				
- Water: m3/ton				
- Water: cost/ton				
- Electricity: KWh/ton				
- Electricity: cost/ton				
- Gas: KWh/ton				
- Gas: custo/ton				
- TEP Total				
- TEP/ton				
People management				
- Accidents with remoteness				
- % Compliance with the training plan				

Figure 61 Template of A3 ME-Goal 2018

Main Initiatives dismember in the area

No.	Description	Responsible	Finish	Gain	Completed %
1	**Control of costs**				
	Track costs weekly by cost per invoice and by commitment- analysis of deviations				
	Renegotiate prices and lead times with critical and higher value suppliers 2018				
	Overtime Control				
2	**Improve OEE Availability ME**				
	Track the TTR, MTTR, MTBF and OEE weekly Availability ME on Table Board				
	Implementation of FMEA for a Foundry cell and a Cell Finishes				
	Improve historical data of ME - Fill of the - Coordinators and ME				
3	**Organization**				
	Management of critical parts availability and audit of the same				
	Rearrange and balance shifts - Foundry and Finishes				
	Visual management - improving scorecards				
	Improve the use of diagnostic analysis tools -> resolution				
	Implementation Lean Maintenance - TPM and 6S				
	Fill the vacancies in the organizational chart ME				
	Implement Kaizen in the ME Department				
4	**Energies**				
	Monitoring of specific energy consumption				
5	**Management of people**				
	Performance Evaluation, Career Plan and Succession Plan ME				
	Behavioral and technical training of the team				
	Monitoring of unsafe acts and unsafe situations - Incidents				

Figure 62 Template Main Initiative in the area ME

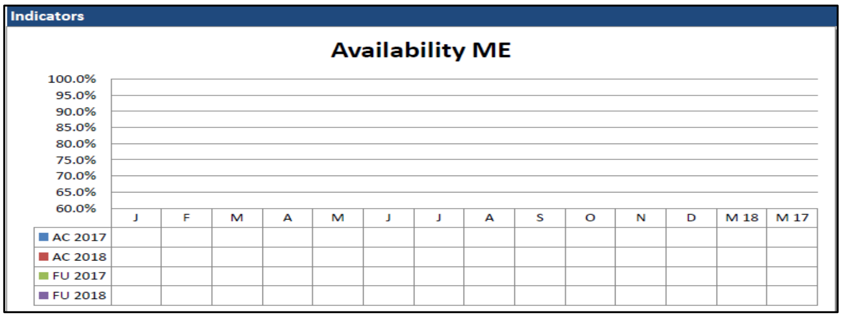


Figure 63 Template of Availability ME

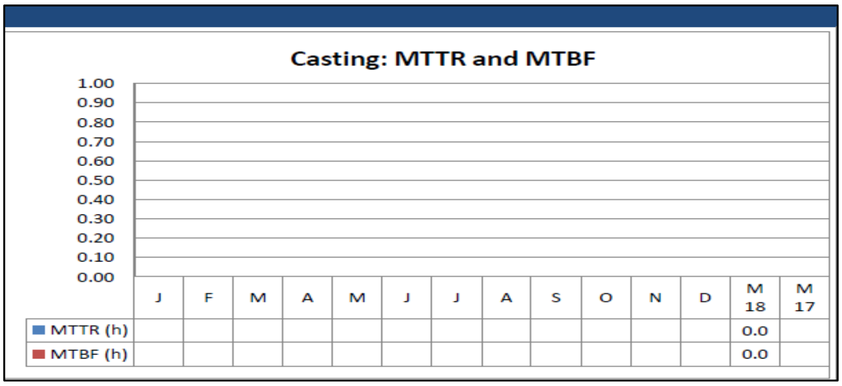


Figure 64 Template of Casting Graph of MTTR Vs MTBF ME

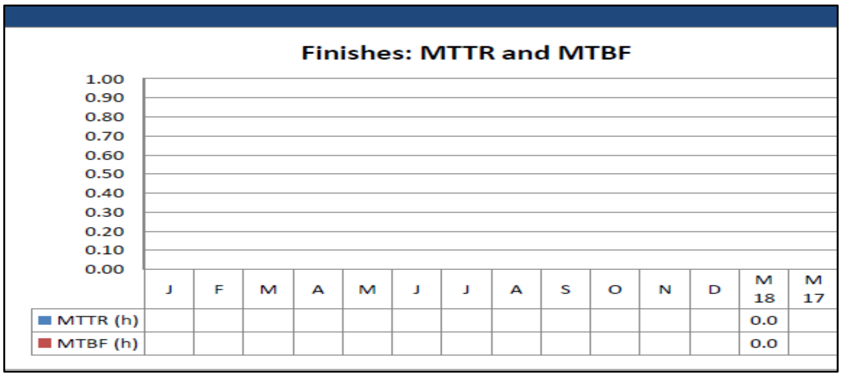


Figure 65 Template of Finishes Graph of MTTR Vs MTBF of ME

3.3.4 Summary of Observation

After the implementation and execution of autonomous maintenance, a reduction in breakdowns was observed on line AA3.

Consequently, one also saw an increase of 2% in the OEE KPI of the machines on line AA3 from April to August 2018. As a result of this factor, there was a significant increase in OEE during the same time period, which directly impacted on the line AA3 production efficiency.

In addition to these improvements, there was an increase in the Mean Time Between Failure (MTBF) of the machines on line AA3, as well as a reduction in the time spent by maintenance technicians on breakdowns repairs. All this was due to the visual management techniques applied to the line machines, which enabled the maintenance technician and operator to rapidly detect the malfunction. In order to calculate these data, one recorded the time, in hours, between failures and the times to repair on all the line’s machines for each month.

CONCLUSIONS

4 CONCLUSION AND PROPOSAL OF FUTURE WORK

The aim of this work was to study, learn, to understand and apply the TPM methodology in the SONAFI. This chapter presents the mains conclusions TPM implementation and the barriers founded in the execution of TPM within the organization. Some future work perspectives are also presented.

4.1 CONCLUSION

This work was developed aiming to implement the Total Productive maintenance function on Die-Casting manufacturing line for the automotive sector. Aimed also to reduce the stoppage rates on machines ensuing from breakdowns. The main objective was achieved through the application of autonomous and Curative maintenance. By following these, operators were able to develop the responsibility to autonomously carry out activities related to cleaning actions, organisation and daily checks of the critical points at the workstation, thus ensuring that their machines and equipment were in good working order. This project resulted in a significant decrease in the number of interventions on the line, and thus contributed greatly to the **2%** increase in the OEE availability of ME. Simultaneously, and as a consequence of these applications, there was also an increase in MTBF, as well as a reduction in MTTR due to the use of visual management practices. These enabled both the operators and maintenance technicians to easily detect a problem on the machines. Solutions were provided for the problems identified and, owing to these results, the company plans to extend the implementation of this improvement technique to other lines. All this was achieved through the use of techniques which directly tackle various types of waste and provide support in the continuous improvement of the process.

4.2 PROPOSALS OF FUTURE WORKS

Since this methodology was developed as a master thesis and thereby during a strict time schedule, further research could put effort in refining the methodology to better suit and represent implementation of TPM in SONAFI.

TPM is widely known for not easy to implement in a short period of time, so is important to monitor the entire process of TPM implemantation over an extended period of time.

4.3 MY EXPERIENCE IN SONAFI

As an intern at the Sonafi I learned the basic structure and operating principles of this Sonafi industry while executing assignments and working with the professional staff. I also present an in-depth analysis of the strengths and weaknesses as well as threats and opportunities available to the Sonafi as identified through a SWOT analysis. After analyzing the basic areas of this Sonafi industry including Foundry, Finished Goods, Ware House & Spare Parts.

My major goal was to build a TPM structure & Pillars and based on the results to identify the recommendations or suggestions for improving of the functioning of the Sonafi as needed. I was concerned with developing an understanding of the methods and principles which could be applied to the Sonafi comparing them to best practices in the field, I suggest recommendations to help remedy the weaknesses, emphasize the strengths and resolve identified problems. The steps required to implement the recommendations suggested are also presented. Finally, I discuss the contribution to the Sonafi including both its short and long-term effects of my participation on the organization.

During my internship I participated in the Daily meetings at the State Department of Maintenance, worked with the Maintenance Manager and all maintenance staffs to prepare for the implementation of TPM and 6S. I have done presentation to all organization from top management to job floor workers in Sonafi about **the importance of TPM**.I collaborate in update the Maintenance manual of TPM. I have worked in various audit in the intern period: Quality Management System Audit IATF 16949:2016 perform by Bureau Veritas, we us a team achieved certification and also by several main Sonafi customers audits in the company like Porche, Groupe Renault France, Valeo, Borg Warner, Renault Nissan, VW, DGH-Group. In Final of intern period I obtained 2% increase in OEE Availability in maintenance department of Sonafi, the main actions were in Autonomous Maintenance and Curative Maintenance. This tool will be a strong impact in near future, because Sonafi had started to implement a TPM Culture it will take time to improve TPM systematic.

Overall, I am very satisfied with the results of my internship. I was able to use my knowledge and apply it to a real Industry. I was able to see some differences in functioning that resulted from my efforts. Due to the character of the internship and the short time period spent at the Sonafi, long-term recommendation would require more work and time, but I took this experience as an opportunity to provide the local Industry with some advanced ideas I learned while a student at the **Instituto Superior de Engenharia do Porto (ISEP).**

4.4 SUPERVISOR EVALUATION

Student Intern Performance Evaluation

Term of Internship: 6 Months (From 5th March to 14th September 2018) Date of Evaluation: 18/09/2018

Student Name: SIVASANGARANE NADARADJANE

Organization Name: Sonafi-National Society of Die Casting Sa

Supervisor: Mr. Carlos Pereira

Supervisor email/phone: carlos.pereira@sonafi.pt/ +351-962513057

Faculty Internship Coordinator: Dr. Sandra Cristina de Faria Ramos /sfr@isep.ipp.pt

Please attach:
- **Internship Job Description**
- **Supervisor Comments** (i.e. strengths, areas for improvement, etc)

Please rate the intern's performance in the following areas:

Rating Scale:
1 = **Excellent** - far exceeded expectations
2 = **Good** - met and exceeded expectations
3 = **Satisfactory** - met expectations
4 = **Fair** - somewhat met expectations, but needs improvement
5 = **Unsatisfactory** - did not meet expectations

1) **Oral communication**	X	2	3	4	5
2) **Written communication**	1	X	3	4	5
3) **Initiative**	X	2	3	4	5
4) **Interaction with staff**	X	2	3	4	5
5) **Attitude**	X	2	3	4	5
6) **Dependability**	X	2	3	4	5
7) **Ability to learn**	X	2	3	4	5
8) **Planning and organization**	1	X	3	4	5
9) **Professionalism**	X	2	3	4	5
10) **Creativity**	1	X	3	4	5
11) **Quality of work**	X	2	3	4	5
12) **Productivity**	1	X	3	4	5
13) **Appearance**	1	X	3	4	5
14) **Adaptability to organization's culture/policies**	X	2	3	4	5
15) **OVERALL PERFORMANCE**	X	2	3	4	5

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JOB DESCRIPTION:

Equipment maintenance
Implementation of TPM - Total Productive Maintenance and,6S, on of the main points of the new standard for automotive industry IATF 16949:2016.

8.5.1.5 of Standard IATF 16949:

The organization shall develop, implement and maintain a documented TPM system, at a minimum it shall include a few points:

- Use methods of Preventive Maintenance
- Use Predictive Maintenance methods
- Documented maintenance objectives: OEE, MTBF and MTTR
- Periodic overhaul

SUPERVISOR COMMENTS:

Sivasangarane Nadaradjane is a student of ISEP currently studying Master's in Mechanical Engineering specialization in Industrial Management applied for an intern post in Sonafi under maintenance department. I had interview with him before appointed him as an intern. He really impressed me with genuine answers and knowledge towards the subjects. I appointed him as an intern under my supervision. Sivasangarane Nadaradjane did a great job in implementation of TPM,6S under IATF 16949:2016 in Sonafi from 5th March to 14th September over a period of 6 month with great enthusiastic and spirit. He worked with various department staffs in maintenance and other department as well in building TPM structure and Pillars of Sonafi. He has done presentation to all organization, from top management to workers in Sonafi, about the importance of TPM. He collaborate in update the Maintenance Manual for TPM. He also worked in various audit in the intern period: Quality Management System Audit IATF 16949:2016 perform by Bureau Veritas, we achieve certification, and also by several main customers audits, Porche, Groupe Renault France, Valeo, Borg Warner, Renault Nissan, VW, DGH-Group. In Final of intern period he obtained 2% increase in OEE Availability in maintenance department of Sonafi, the main actions was in Autonomous Maintenance and Curative Maintenance. This tool will be a strong impact in near future, because we had start implement a TPM Culture, will take time to improve team building and TPM systematic, is a day by day task, this is the legacy from Sivasangarane.
Intern excels at: Professionalism, Knowledge of academic study, Communication, Organization and interpersonal relationships
Intern needs to work on: Professional appearance.
Additional Comments: I am very glad I was able to work with him for his semester internship and would welcome him full time with our company if he so wished. He is a fine asset and recognizes his abilities.

REVIEWER COMMENTS ABOUT REVIEW:

The Review was truly done based on the work done by the intern without any compromise or adjustment.

INTERN ACKNOWLEDGEMENT: I have reviewed all pages of this document and have discussed the contents with my supervisor. My signature means that I have been advised of and fully understand my performance status.

Intern Signature and Date
18/9/2018

Supervisor Signature and Date
18/9/2018
SONAFI – Sociedade Nacional de Fundição Injectada, SA

REFERENCES AND OTHER SOURCES OF INFORMATION

5 REFERENCE AND OTHER SOURCES OF INFORMATION

5.1 REFERENCE AND OTHER SOURCES OF INFORMATION

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ANNEXES

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6 Annexes

6.1 Annex1

CPM Tracking:

CPM Tracking

Status Detail
Completed
Waiting
Delay

Week	Date	Task Name	Task assigned by	Task estimated on	Status of the task	Notes	Reviewed by
1st week	05-03-18 06-03-18 07-03-18 08-03-18 09-03-18	Detail study about Implementation of TPM along with kaizen, IAFT,OEE, IAFT 16949:2016 based on TPM	Carlos	09-03-18	Completed	Complete Review in the end of quality manual of TPM	Carlos
	10-03-18 11-03-18						
2nd week	12-03-18 13-03-18 14-03-18 15-03-18 16-03-18	Design of quality manual of TPM (Sonafi)	Carlos	16-03-18	Completed	Complete Review in the end of quality manual of TPM	Carlos
	17-03-18 18-03-18						
3rd week	19-03-18 20-03-18 21-03-18 22-03-18 23-03-18	merging of IATF with TPM , finalizing the clauses, design of quality manual draft	Carlos	23-03-18	Completed	Complete Review in the end of quality manual of TPM	Carlos
	24-03-18 25-03-18						
4th week	26-03-18 27-03-18 28-03-18 29-03-18	Completing the manual work and preparing for the audit, analyse and learning the company process	Carlos	29-03-18	Completed	Manual is completed along with that audit is also done regarding TPM work	Carlos
	30-03-18 31-03-18 01-04-18						
5th week	02-04-18 03-04-18 04-04-18 05-04-18 06-04-18	Analyzing all the departments in Sonafi under maintenance regarding implementing the TPM	Carlos	06-04-18	Completed	analyzed all the departments are done succesfully	Carlos
	07-04-18 08-04-18						
	09-04-18 10-04-18 11-04-18	Documented all the departments in Sonafi under maintenance regarding	Carlos	13-04-18	Completed	Documented all the departments in sonafi	Carlos

6th week	11-04-18 12-04-18 13-04-18	Sonafi under maintenance regarding implementing the TPM	Carlos	13-04-18	Completed	departments in sonafi are done succesfully	Carlos
	14-04-18 15-04-18	HOLIDAY Sturday/Sunday					
7th week	16-04-18 17-04-18 18-04-18 19-04-18 20-04-18	Preparing Powerpoint presenting the implementation of TPM draft	Carlos	20-04-18	Completed	Power point is prepared for implementation of TPM draft	Carlos
	21-04-18 22-04-18	HOLIDAY Sturday/Sunday					
8th week	23-04-18 24-04-18 25-04-18 26-04-18 27-04-18	working on acabamentos to implement tpm,discussing on other pillars of TPM,Analyzing the preventive maintenance department	Carlos	27-04-18	Completed	Workdone as per the schedule assigned	Carlos
	28-04-18 29-04-18	HOLIDAY Sturday/Sunday					
9th week	30-04-18 01-05-18 02-05-18 03-05-18 04-05-18	Analyzing the work done so far,Prepare for the auditing,working on filtering of critical spare parts	Carlos	04-05-18	Completed	Workdone as per the schedule assigned	Carlos
	05-05-18 06-05-18	HOLIDAY Sturday/Sunday					
10th week	07-05-18 08-05-18 09-05-18 10-05-18 11-05-18	Analyzing the qualification of human resources, quality, cleaning and finalizing the ppt of implementation of TPM	Carlos	11-05-18	Completed	Workdone as per the schedule assigned	Carlos
	12-05-18 13-05-18	HOLIDAY Sturday/Sunday					
11th week	14-05-18 15-05-18 16-05-18 17-05-18 18-05-18	Finalizing and presenting the ppt to maintenance coordinators of sonafi	Carlos	18-05-18	Completed	Workdone as per the schedule assigned	Carlos
	19-05-18 20-05-18	HOLIDAY Sturday/Sunday					
12th week	21-05-18 22-05-18 23-05-18 24-05-18 25-05-18	Presenting to kaizen and sonafi chief coordinators about implementation of TPM	Carlos	25-05-18	Completed	Presenting to sonafi chief coordinator is yet to be done	Carlos

	26-05-18 27-05-18	HOLIDAY Sturday/Sunday					
13th week	28-05-18 29-05-18 30-05-18 31-05-18 01-06-18	Presenting to sonafi chief coordinators and presenting the new ppt for technician about implementation of TPM	Carlos	01-06-18	Completed	Presenting to sonafi chief coordinator is yet to be done	Carlos
	02-06-18 03-06-18	HOLIDAY Sturday/Sunday					
14th week	04-06-18 05-06-18 06-06-18 07-06-18 08-06-18	Working on 6S,sonafi company Thesis part	Carlos	08-06-18	Completed	Presenting to sonafi chief coordinator is yet to be done	Carlos
	09-06-18 10-06-18	HOLIDAY Sturday/Sunday					
15th week	11-06-18 12-06-18 13-06-18 14-06-18 15-06-18	Working on TPM, Thesis work,Presenting to coordinator	Carlos	15-06-18	Completed	Presenting to the sonafi CEO is done, Workdone as per the schedule assigned	Carlos
	16-06-18 17-06-18	HOLIDAY Sturday/Sunday					
16th week	18-06-18 19-06-18 20-06-18 21-06-18 22-06-18	Working on TPM Curative Maintenance	Carlos	22-06-18	Completed	Workdone as per the schedule assigned	Carlos
	23-06-18 24-06-18	HOLIDAY Sturday/Sunday					
17th week	25-06-18 26-06-18 27-06-18 28-06-18 29-06-18	Working on TPM Continous Improvements	Carlos	29-06-18	Completed	Workdone as per the schedule assigned	Carlos
	30-06-18 01-07-18	HOLIDAY Sturday/Sunday					
18th week	02-07-18 03-07-18 04-07-18 05-07-18 06-07-18	Working on TPM thesis , autonomous maintenance, portuguese presentation to technician,sub-coordinators.	Carlos	06-07-18	Completed	Workdone as per the schedule assigned	Carlos
	07-07-18 08-07-18	HOLIDAY Sturday/Sunday					
	09-07-18 10-07-18	Presenting to operator,Technician				Workdone as per the	

19th week	11-07-18 12-07-18 13-07-18	about TPM, working along with kaizan in implementation of TPM	Carlos	13-07-18	Completed	Workdone as per the schedule assigned	Carlos
	14-07-18 15-07-18	HOLIDAY Sturday/Sunday					
20th week	16-07-18 17-07-18 18-07-18 19-07-18 20-07-18	Preparing checklist for TPM ,working on 6S	Carlos	20-07-18	Completed	Workdone as per the schedule assigned	Carlos
	21-07-18 22-07-18	HOLIDAY Sturday/Sunday					
21th week	23-07-18 24-07-18 25-07-18 26-07-18 27-07-18	Preparing checklist for TPM ppt portuguese ,working on 6S progress	Carlos	27-07-18	Completed	Workdone as per the schedule assigned	Carlos
	28-07-18 29-07-18	HOLIDAY Sturday/Sunday					
22nd week	30-07-18 31-07-18 01-08-18 02-08-18 03-08-18	Preparation of portuguese tpm and importance and presenting to technician,coordinators,to all shifts in sonafi	Carlos	03-08-18	Completed	Workdone as per the schedule assigned	Carlos
	04-08-18 05-08-18	HOLIDAY Sturday/Sunday					
23rd week	06-08-18 07-08-18 08-08-18 09-08-18 10-08-18	Working on Thesis, implementation of 6S	Carlos	08-10-18	Completed	Workdone as per the schedule assigned	Carlos
	11-08-18 12-08-18	HOLIDAY Sturday/Sunday					
24th week	13-08-18 14-08-18 15-08-18 16-08-18 17-08-18 18-08-18 19-08-18	Summer Vacation					
25th week	20-08-18 21-08-18 22-08-18 23-08-18 24-08-18	Presentation to ME team and working on thesis	Carlos	24/8/2018	Completed	Workdone as per the schedule assigned	Carlos
	25-08-18	HOLIDAY Sturday/Sunday					

	26-08-18	HOLIDAY Sturday/Sunday					
26th week	27-08-18 28-08-18 29-08-18 30-08-18 31-08-18	Presentation to production team-1 and working on thesis	Carlos	31/8/2018	Completed	Workdone as per the schedule assigned	Carlos
	01-09-18 02-09-18	HOLIDAY Sturday/Sunday					
27th week	03-09-18 04-09-18 05-09-18 06-09-18 07-09-18	Presentation to production team-2 and working on thesis	Carlos	09-07-18	Completed	Workdone as per the schedule assigned	Carlos
	08-09-18 09-09-18	HOLIDAY Sturday/Sunday					
28th week	10-09-18 11-09-18 12-09-18 13-09-18 14-09-18	Presentation to production team-3 and working on thesis	Carlos	14/9/2018	Completed	Workdone as per the schedule assigned	Carlos
	15-09-18 16-09-18	HOLIDAY Sturday/Sunday					