ISCTE Business School
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DEVELOPING A MODEL TO ANALYSE THE OVERALL EQUIPMENT EFFECTIVENESS IN ORDER TO ADD VALUE IN A B2B CONTEXT

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Abstract

Nowadays, due to the increasing competition level, companies must find ways to differentiate. Service development can be a differentiating factor when compared to low-cost competitors. It may provide ways to identify and address specific customer needs by delivering innovative business solutions by regular support and direct contact, which can ultimately be translated into a source of competitive advantage.

This business project emerges from the need of the company to improve its competitive position. Following a market analysis, it was concluded that the way to do it was to focus on a specialized range of services centred on industrial systems automation, offering a standardized portfolio of automation products as the basis for customized solutions. To this end, the company has created a questionnaire that allows it to get an overview of the customers' plants' procedures and identify their equipment's failures and needs.

The goal of this business project consists on developing a model that, through the results analysis of the questionnaire, generates recommendations based on the company's products, which will allow the company to solve the previously identified failures and add value to its customers. The philosophy used in creating the recommendations is the Total Productive Maintenance. Moreover, the model has been tested by a real customer to verify its feasibility.

In the future, the expected outcome is to link these recommendations to potential services that will enable the company to offer not only products but a solution containing the product and all activities necessary for its best working performance.

Key-words: Service Development; Total Productive Maintenance; Overall Equipment Effectiveness; Root Cause Analysis.

JEL Classification: L80, O14

Sumário

Atualmente, devido ao crescente nível concorrencial, as empresas necessitam de identificar formas para se diferenciar. O desenvolvimento de serviços pode ser um fator diferenciador no relacionamento entre empresa e cliente comparativamente com os concorrentes de baixo custo. Através dos serviços, é possível identificar e atender às necessidades específicas dos clientes, oferecendo soluções comerciais inovadoras através de suporte regular e contacto direto, o que se pode traduzir numa fonte de vantagem competitiva.

Este projeto surge da necessidade da empresa melhorar a sua posição competitiva. Após análise do mercado, concluiu-se que a estratégia para o fazer seria através do foco numa gama especializada de serviços focados na automação de sistemas industriais, oferecendo um portfólio padronizado de produtos na área da automação como base para a oferta de soluções personalizadas. Para isso, a empresa criou um questionário que permite obter uma visão geral dos procedimentos nas fábricas dos clientes, e detetar as suas falhas e necessidades.

O objetivo deste projeto passa por desenvolver um modelo que, através dos resultados do questionário, tem a capacidade de gerar recomendações, baseadas nos produtos da empresa, que permitam solucionar as falhas previamente identificadas, gerando valor aos seus clientes. A filosofia utilizada na criação das recomendações é a *Total Productive Maintenance*. O modelo foi testado por um cliente real para verificar a sua viabilidade.

No futuro, a intenção será vincular as recomendações a potenciais serviços que permitirão à empresa oferecer não apenas produtos, mas uma solução constituída pelo produto e todos as atividades necessárias à sua melhor funcionalidade.

Palavras-chave: Service Development; Total Productive Maintenance; Overall Equipment Effectiveness; Root Cause Analysis.

Classificação JEL: L80, O14

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List of Acronyms and Abbreviations

ACV – Actuator-Controller and Valve

CMMS – Computerized maintenance management systems

CPS – Cyber-Physical Systems

DM – Data Mining

IoS – Internet of Service

IoT – Internet of Things

JIPM – Japan Institute of Plant Maintenance

JIT – Just-In-Time

LCC – Life Cycle Cost

OEE – Overall Equipment Effectiveness

PAT – Process Analytical Technology

PoS – Product-oriented services

P-S – Porduct-Sercice

PSS – Product-Service Systems

RCA – Root Cause Analysis

RCM – Reliability Centred Maintenance

RMS – Reconfigurable Manufacturing Systems

RoS – Result-oriented services

RQs – Research Questions

TPM – Total Productive Maintenance

TPS – Toyota Production System

UoS – User-oriented services

1. Introduction

1.1. Background

This Master Thesis is written in the format of a business project since it was developed in a German company and, therefore, focuses on its specific context.

This company is present in sixty-two countries worldwide and it is segmented into five different business units: the pneumatic factory-automation, which is the main unit, the electronic automation unit, the customer solutions unit, the process automation unit and an own didactic subsidiary that focuses only on training and didactics. This business project focuses on the process-automation business unit where the Future Concepts department team is incorporated and where the internship was performed.

In Figure 1, it is possible to observe the trends chart of this department strategy supported by three different categories. The first category focuses on the development of innovations for new topics and working fields by analysing competition's technologies and innovation processes. The second one is the Optimisation with Process Analytical Technology (PAT) which consists in developing ways and tools to increase plant efficiency. The last one is the Smart Modular Systems category which objective is to find opportunities through the study of emerging future trends in order to maintain the company competitive in the market.

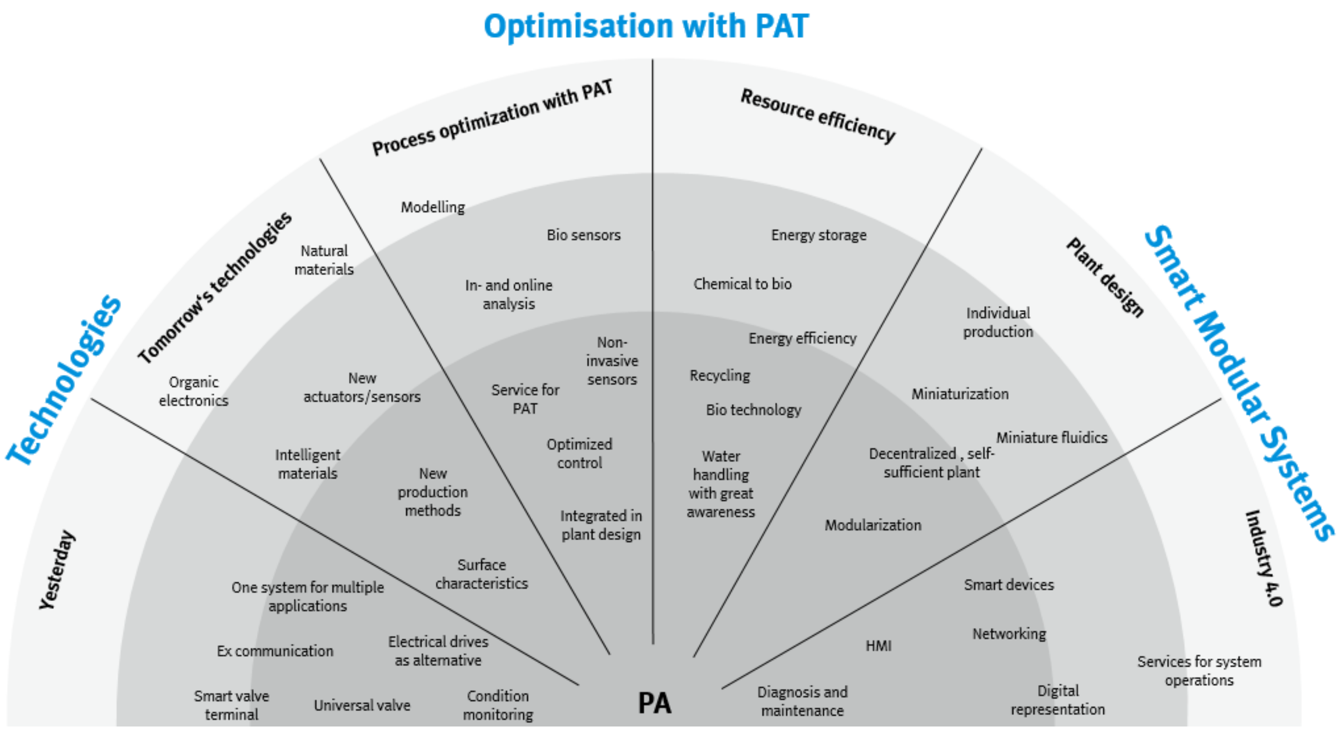

Figure 1 - Future Concepts Trends Chart (Source: Company)

This business problem will be developed and integrated on the last topic of Smart Modular Systems in the Industry 4.0 segment that is divided into different clusters. The project has its focus on a trend that emerged through the study of the Services for System Operations cluster.

1.1.1. Service Provider

The Future Concepts department, following the trend strategy of creating a unique selling proposition in process automation with services, intends to evaluate the components of the customers' plants, outline their needs and services potential and, later, improve customers' satisfaction and loyalty levels.

In 2010s the company had no service strategy implemented in the process automation. With the increasing comparability of products on the market and the increase of customer expectations to holistic care including product-related services, technical features started to not be enough to convince customers alone. This conducted to the company becoming more aware of service importance and resulted in its willingness to create a unique selling point in order to raise the company from other competitors in the process automation.

In the developing process of the service strategy, it was decided to use the Overall Equipment Effectiveness (OEE). OEE is a metric to assess and evaluate customer availability, quality, and performance, in TPM context (Nakajima, 1988). By creating a tool to index these parameters, it will enable the assessment of the customer real plant needs and will give the company a clear overview of what could be included in the new product development process by coordinating the research and development department more customer-oriented.

1.1.2. ACV-Fingerprint

To accomplish this, The Future Concepts Team created the evaluation tool (*vide Appendix 1*) to index the overall equipment effectiveness of the customers' plants, using brainstorming and other techniques. It consists in a customer-oriented questionnaire with forty-eight questions split over four different workbooks, covering the following dimensions: 1. Organization, 2. Lifecycle and Production, 3. Plant-specs and Reliability and, 4. Maintenance. Every question is rated from 1, the best score, to 6, the worst, being each rate allocated to an answer in order to simplify the score attribution. This tool is applied in a face-to-face interview between one salesperson from the company and the customer. The result of this questionnaire could help customers to access information about their plant needs and a comparison of their results with the best practices in the industry. These best practices were developed and detailed by the Future Concepts team, operationalized through an Excel spreadsheet.

For this purpose, a radar chart (Figure 2) is generated where is represented the evaluation of the next seven parameters: 1. Availability; 2. Performance; 3. Quality; 4. Reliability; 5. Employees; 6. Life cycle management; 7. Materials and resources are presented to customers.

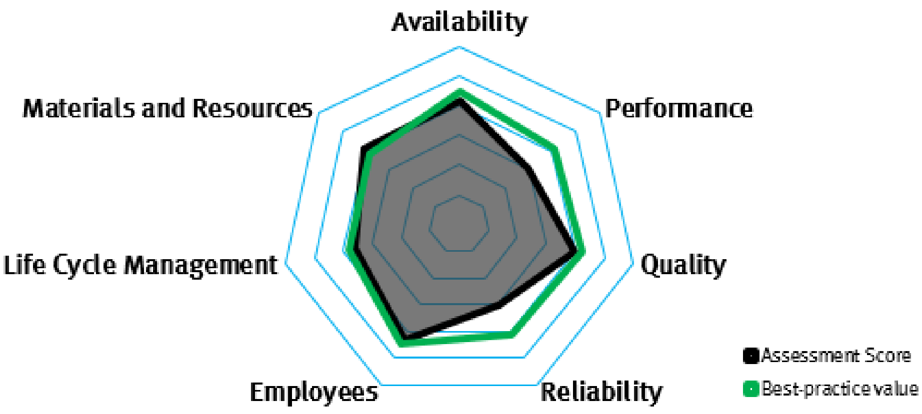

Figure 2 - ACV-Fingerprint Questionnaire evaluation example

1.1.3. Industry 4.0

Nowadays, according to Ahamed et al. (2013), it has been observed a significant trend in the manufacturing industry that the firms are shifting their business from not only producing goods to offering an integrated package of goods and services.

To answer the changing market conditions, manufacturing companies have started adding more services to their total offerings as part of a differentiation strategy (Gebauer et al., 2010; Oliva and Kallenberg, 2003). Companies with greater reliance on the service part of their business reportedly achieve a better return on sales and improve their value (Fang et al., 2008). Quoting Neely (2008), the point is that to survive, manufacturing firms rarely appear to remain as pure manufacturing firms.

Industry 4.0 focuses on the establishment of intelligent products and production processes. In future manufacturing, factories must cope with the need for rapid product development, flexible production as well as complex environments (Brettel et al., 2014; Vyatkin et al., 2007).

According to Brettel et al. (2014), within a smart factory, products can communicate with their environment and influence the arrangement of Reconfigurable Manufacturing Systems (RMS). Concrete structures and specifications of production processes are replaced by configuration rules, from which case-specific topologies can be derived automatically. RMS enables manufacturing companies to adapt to changing production requirements in a cost-efficient way. Machine components can be added, removed or rearranged depending on their mechanical module interface (Abele et al, 2007). Moreover, the emergence of digital technologies has lately enabled companies to dematerialize physical offerings and provide smart and connected products and services (Kamp and Parry, 2017).

In general, Industry 4.0 tools may consist of four components: (1) Cyber-Physical Systems (CPS) of the third generation can store and analyse data, are equipped with multiple sensors and actuators, and are network compatible; (2) Internet of Things allows “Things or Objects” interact with each other and cooperate with their “smart” components to reach common aims (IoT). So, CPS can be defined as “Things or Objects”. Therefore, the IoT can be thought of as a network where CPS cooperate through unique addressing schemas; (3) Data Mining - DM enables users to analyse and discover patterns, rules, and knowledge from big data collected from multiple sources. Users can make the right decision at the right time and right place; (4) Internet of Service – IoS Services are offered and combined into value-added services by various suppliers. They are communicated to users as well as consumers and accessed by them via various channels (Wang, 2016), the way it is presented in Figure 3.

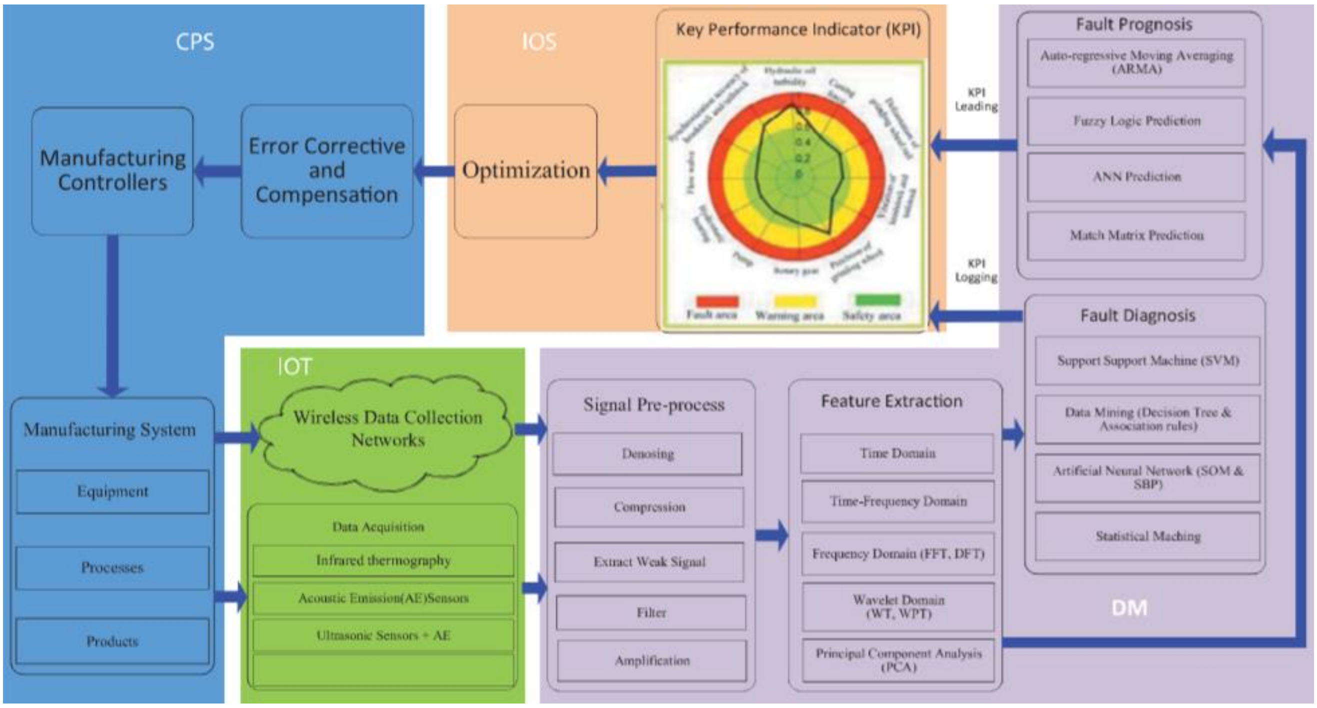

Figure 3 - Framework of Intelligence Predictive Maintenance (IPdM) systems in Industry 4.0 (Source: Wang, 2016)

This company is no exception to this situation. In a market where the awareness for the process automation topic is increasing over the years, the company wanted to expand its competitive position to be among the top providers worldwide in selected product segments in the long term.

To achieve a leading position in the four selected target industry segments of biotech/pharma, industrial water, food processing and chemicals, the company decided to rely on a specialized range of services for the automation of industrial systems, offering a standardized product portfolio in the area of field automation as a basis for designing customized solutions for the customers in plant engineering. In this context, it arises the need to assess customer's needs which resulted in the creation of the ACV-Fingerprint questionnaire, explained above.

1.2. Customer Compass - A Model to Solve the Business Problem

This project emerges from the need to find a way to analyse the data from this questionnaire and to add value both to the company and its customers. For that, a model capable of offering answers and procedures to clients according to the questionnaire results will be developed. This model will contain recommendations according to the industry's best practices. A best practice is a technique or methodology that is found to be the most effective and has consistently shown to achieve superior results.

The name of this model stands for the compass as the instrument that shows the path that walkers should take. In this context, the goal of this model is to *lead the customer to achieve the best performance that they could have by pointing out the best path to take*. Its purpose consists in enabling the company to assess customer's plant failures, to understand the customers' needs in the plant process context and to start developing new products oriented to real-existing customer needs. By providing recommendations to their specific plant needs, the company will also improve customer satisfaction and loyalty to the company. Also, through this ongoing contact with the customer, it will enable the company to not miss an upcoming demand which will secure the future-proof orientation of the company.

This model, entitled Customer Compass, will be explained in detail in Chapter 4 - Methodology.

1.3. Research Questions

To achieve the goal of this master thesis previously defined, this research will try to answer the following Research Questions (RQs):

1) How to develop recommendations that add value to both the company and its customers based on the ACV-Fingerprint result?
2) Which methodology could be used to help structure problem resolution?
3) How to understand the causes and impacts of the questions provided by the ACV-Fingerprint?
4) Which recommendations could be developed to overcome the impacts obtained?

1.4. Methodology

The development of this business project started in September of 2017 and finished at the end of July of 2018. All the procedures and executions were performed in-company context during an internship of 10 months in a company located in Germany.

In order to answer the proposed research questions, the main topics associated with Servitiziation, Total Productive Maintenance and Overall Equipment Effectiveness, focusing on the specific objective to create recommendations, a systematic Literature Review was conducted. According to Boland et al. (2014), this type of review allows the researcher to evaluate, condense and synthesize the best evidence related to a specific research question or topic of interest. Subsequently, a Root Cause Analysis methodology was used to discover the prime causes of a failures that were previously identified through the collection of data by the application of the ACV-Fingerprint questionnaire. The choice of this path to pursue the research is mainly due to the fact that this tool consists in a step-by-step methodology that provides a structured way to obtain the causes and impacts for failures and helps to obtain information regarding the customers' answers to the questionnaire and, so, achieve the main objective of this business problem, which is the development of the customers' recommendations. Moreover, a case study strategy was pursued, where the project sponsor provided the case to test the developed solution. Further details about how the research was conducted will be provided in the Chapter 4.

1.5. Business Problem Report Structure

This business problem report contains five chapters:

Chapter 1 - Introduction

In this chapter, it is possible to gain general information about the company and it is explained the reason for developing this business project. It presents the problems that the student wants to solve, as well as the objectives and research questions of this business problem.

Chapter 2 - Literature Review

The second chapter consists in a more detailed contextualization of the theme of this business project. It begins with the need to explain how services are becoming crucial to add value to manufacturing companies (Servitization). Then, the role of Maintenance and Total Productive Maintenance (TPM) is referred to understand the best practices of maintenance in the industry. Last, it will be demonstrated how the TPM approach improves the OEE of the customers' plants.

Chapter 3 - Conceptual Framework

This chapter consists in analysing the topics presented in the literature review in order to understand how the problem could be solved. It consists into summarizing the main emerging topics of interest for the business project research where the most relevant aspects emerged, which permitted to find the main propositions. This also enables the formulation of the graphical representation of the conceptual framework that will map and synthesize the schematic form of the relevant aspects that emerged from the literature review.

Chapter 4 - Methodology

This chapter includes the methodology that aims to describe and explain how the research was conducted, highlighting the methods and strategies that were used in order to answer the research questions and achieve the objectives. To answer the research questions initially formulated, it was essential to collect the proper data to enable it to happen, which was also explained in this chapter.

Chapter 5 - Analysis

In this chapter the model previously developed is tested on a real customer of the company and the results of this implementation are presented and analysed in order to prove the value-added to the customer.

Chapter 6 - Discussion and Conclusions

The final chapter presents a discussion of the main propositions (*vide section 3.1*), the project contributions of this business problem and its answers to the RQs.

Additionally, the study limitations are presented and suggestions for future works considered.

2. Literature Review

The purpose of the literature review is to determine if a topic is researchable, to report the results of closely related studies, and to establish the importance of the current study in relation to previous studies (Creswell et al., 2003). To do a proper literature search, according to Bell (2014), it is also important to have in mind how each topic will contribute to the previously presented research questions. Knowing this, the following literature review will begin with an introduction of the Servitization concept, explaining how services are becoming crucial for manufacturing companies' competitive advantage. The focus will rely on the specific purpose of the company in providing services: improve the customers' plants' overall equipment effectiveness. For this, the information required regarding the role of Maintenance and TPM is studied, in order to understand the best practices in the industry. Last, it will be demonstrated why it was chosen the Total Productive Maintenance approach to explain how the OEE of the customers' plants can be improved.

2.1. Servitization

The first use of the term Servitization in the context of manufacturing operations was by Vandermerwe and Rada (1988). They described how companies initially considered themselves to be in goods or services (e.g. product manufacture or insurance), and then moved to offering goods combined with closely related services (e.g. products offered with maintenance, support, finance), and finally to a position where 'firms offer bundles consisting of customer-focused combinations of goods, services, support, self-service, and knowledge'. In the customer perspective, Servitization allows that the relationship with customers improves from being a relationship of buying and selling (transactional) to start being closer and constant relationship (relational) (Oliva and Kallenberg, 2003).

In the literature, Servitization is referred to as the Product-Service (P-S) transition and represents the transition between pure product to pure service offerings (Oliva and Kallenberg, 2003; Tukker, 2004). Within this transition exists combinations of products and services known as Product-Service Systems (PSS). A link of the Product-service system (PSS) with Servitization is also identified by Baines et al. (2007) who defined PSS as an integrated combination of products and services that deliver value in use.

For the customer, PSS is seen as a feature that provides value through more customization and higher quality. It is often described as the removal of administrative or monitoring tasks from the customer to the manufacturer (Cook et al., 2006). Service delivery and enhanced interactions increase the value of customer service while increasing customer satisfaction (Auh et al., 2007), developing customer relationships, loyalty and commitment to the supplier (Grönroos and Helle, 2010). Tukker (2004) also explained that there were at least three categories of business models, as it is possible to observe in Figure 4.

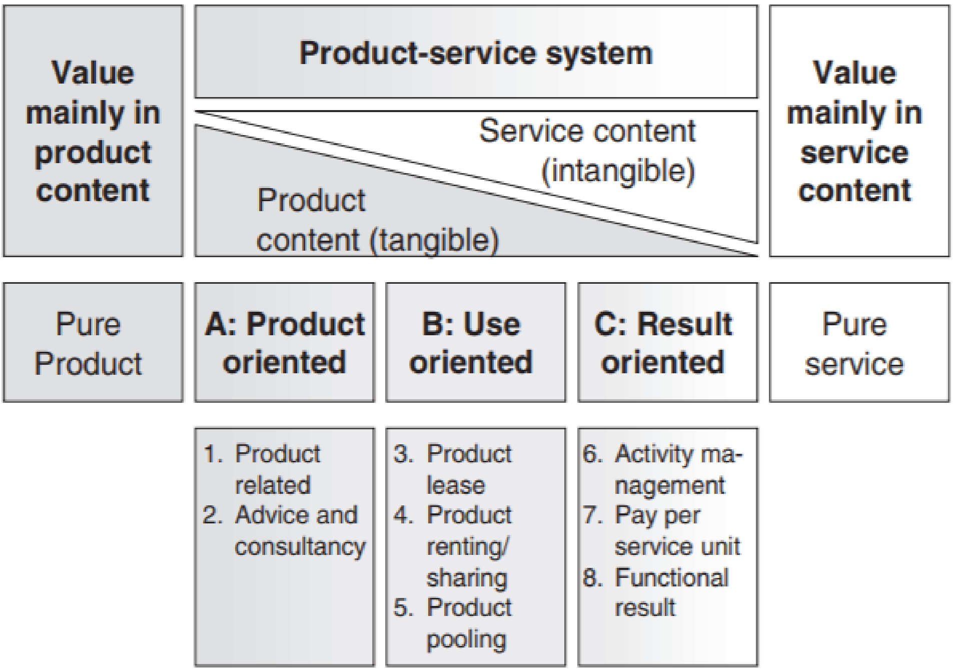

Figure 4 - Main and subcategories of PSS (Source: Tukker, 2004)

Each category itself includes PSS with quite different economic and environmental characteristics. Following a typology developed in a Dutch PSS manual (Tukker and Van Halen, 2003), it is possible to identify more specific PSS types that are described next.

The first category is Product-oriented services (PoS). Here, the business model is focused mainly on the sale of products, to which are added some extra services. Subcategories are product-related services and advice and consulting (Tukker, 2015).

The second category is the User-oriented services (UoS). Here, the traditional product still plays a central role, but the business model is not geared to the sale of products. The product is owned by the supplier and is made available to the customer in three different ways (subcategories). The subcategories are product leasing, renting or product sharing or product pooling (Tukker, 2015). In this category, the risks and responsibilities of the supplier are greater than in the category of PoS (Reim et al., 2015).

The last category is Result-oriented services (RoS). Here the customer and the supplier agree on a result and there is no predetermined product involved. The subcategories are activity management/outsourcing or payment service per service unit (Tukker, 2015). In this category, since the supplier is free to use the inputs that want to provide the previously established results, the responsibility and risk are greater than in the case of UoS.

In this business problem, Servitization concept is crucial since the company intends to add value to its customers by providing maintenance services to its customers so that both benefit from it. The idea is to start by providing recommendations to overcome the major customers' plant failures that are obtained through the ACV-Fingerprint questionnaire and then create solutions associated with them. To develop these recommendations, maintenance literature had to be studied in order to understand the role of maintenance in manufactory companies.

2.2. The Role of Maintenance

Since maintenance is the core activity of the company, a brief description of the role of maintenance over the past decades will be provided next. Three strategies are addressed: breakdown maintenance, preventive maintenance, and predictive maintenance. It is important to note that predictive maintenance is associated with the current planned maintenance, which is a pillar of the Total Productive Maintenance that is going to be discussed next.

The history of the systematic maintenance approach is short when comparing it to the industrial age. Considerably far, as long as the 1960s' maintenance was equivalent to extinguishing the fire. In the beginning, the primary function of maintenance was to get equipment back up and running (Hamacher, 1996). The effectiveness of maintenance was measured in time of fixing broken equipment. As late as the 1970s', it was recognized that maintenance should be performed in a way that aimed to prevent breakdowns. Nowadays, by developing an optimized maintenance strategy and approach, it is possible to achieve great impacts on the overall business performance (Artiba et al., 2005).

Generally, maintenance was categorized into two major strategies: corrective maintenance and preventive maintenance (Waeyenbergh and Pintelon, 2002). Broader categories can also be found, as follows:

- Breakdown Maintenance - This refers to the corrective maintenance strategy, where maintenance is done when equipment fails, or the equipment performance declines. In this type of maintenance machines are repaired when maintenance is drastically required. (Jain et al., 2014). Corrective maintenance is also known as a breakdown, failure based, run-to-failure or unplanned maintenance which is a classic maintenance type where the equipment is used until it breaks down/fails by simply performing a job repair and service the component of equipment. Corrective maintenance can be justified when the impact of the failure is tending to small. In corrective maintenance mode, failure can be occurring at any time in many ways and sometimes when it happens at an improper time can result in greater costs than expected (Lind and Muyingo, 2012).
- Preventive Maintenance – This refers to the maintenance in which a physical check-up of equipment is performed to detect, prevent or to mitigate degradation of the components or systems in order to extend the lifetime of equipment by controlling degradation at acceptable levels (Sullivan et al., 2010). The approach of preventive maintenance mechanism would be more beneficial to the long-term strategy for the economic life of the equipment, it is because the cost of preventive maintenance activity is smaller than corrective maintenance activity in the same period during the life cycle asset, or the whole lifecycle of the equipment (Velmurugan & Dhingra, 2015). Time-Based Maintenance is a type of Preventive Maintenance activity that is scheduled based on maintenance in an appropriate interval of time like daily, weekly or monthly (Sharma et al., 2012).
- Predictive Maintenance - The third strategy is predictive maintenance takes Condition Based Maintenance to the next level by providing real-time monitors for equipment parameters (for example voltages, currents, clearances, flows, etc) (Pomorski, 2004). Condition-Based Maintenance, also known as Predictive Maintenance, attempts to evaluate the condition of an asset by performing continuous asset monitoring. Condition monitoring is the process of collecting measurable, quantifiable performance indicators from assets. Predictive maintenance is scheduled based on measured wear, variation, or degradation on equipment as a result of production stresses. It is more suitable than Time-based Maintenance as it is scheduled based on the stress and deterioration that production activity places on equipment rather than just a pre-set period (Sharma et al, 2012).

- Reliability Centred Maintenance – This maintenance is a systematic approach to evaluate the availability of equipment and resources to be integrated and produce a good level of equipment reliability and expected to improve cost-effectiveness. RCM identifies that the entire equipment at a facility has different interests in terms of both the process and of its security facilities. The RCM approach is to manage the maintenance program, where limited financial resources and personnel availability are considered, the use of both must be optimized and determined by priority (Sullivan et al., 2010). The goal of RCM is to determine what the critical components in any process are and, based on this information, design a customized preventive/predictive maintenance strategy (Eti et al., 2006).
- Computerized maintenance management systems – CMMS are used to manage a wide range of information on the maintenance workforce, spare-parts inventories, repair schedules and equipment histories (Jain et al, 2014).

The evolution of Maintenance is provided by Willmott (1994) by Figure 5.

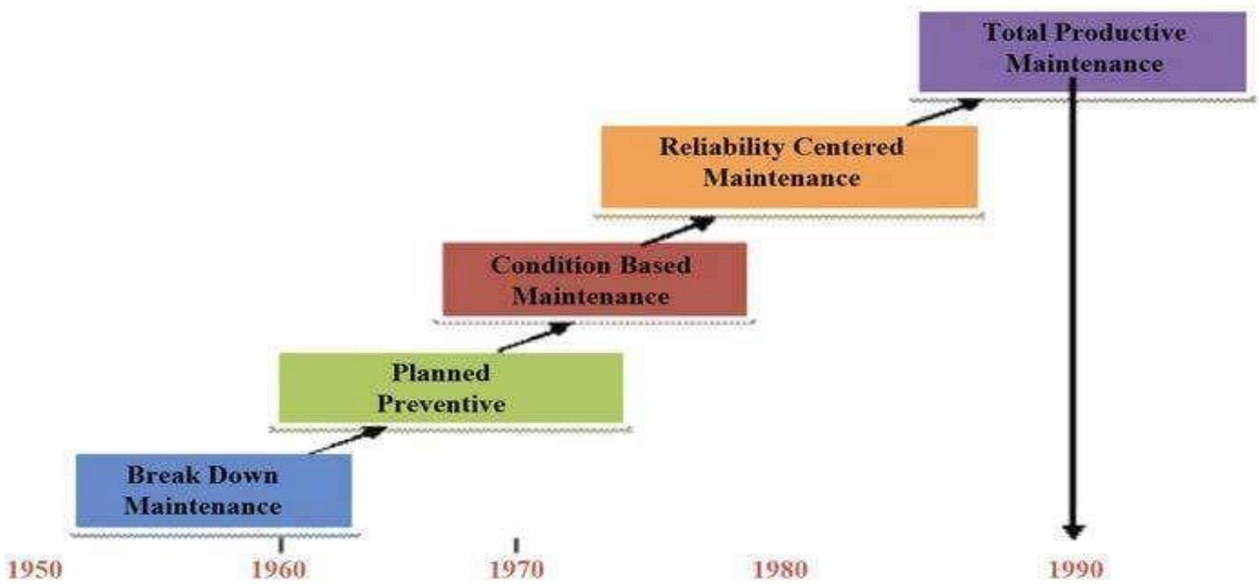

Figure 5 - Evolution of Maintenance (Source: Willmott, 1994)

As attention to environmental problems grows, product life cycle management becomes a crucial issue in realizing a sustainable society. The purpose of product life cycle management is to control the conditions of products and provide the functionality required by customers or by society while keeping the environmental load at a minimum and maintaining appropriate corporate profits. There are two reasons why it is necessary to control the conditions of products. One is the change in product conditions due to deterioration. Another is the changing needs of customers or society. The former is referred to as the product's physical life and the latter as its functional life. In both cases, the measure that should be considered first is maintenance including upgrade, because maintenance generates less environmental load. If maintenance does not work well, other measures should then be considered, such as remanufacturing. Production of new products should be the last measure taken (Takata et al., 2004). Maintenance could be one of the major services associated with product life cycle management. If this business transformation goes further, companies will sell utilization and customers will pay only for utilization. In this context, achieving effective maintenance could be of benefit to companies, which can increase profit by the reduction of maintenance costs, as well as to customers who can enjoy the improvement of service quality (Seliger et al., 2002).

In this strategy, the focus should be on investigating and purchasing the technology that solves or mitigates chronic equipment-problems. Predictive Maintenance inspections should be planned and scheduled utilizing the same techniques that are used to schedule the Preventive Maintenance tasks. All data should be integrated into the CMMS (Eti et al., 2014). Predictive maintenance is to monitor the elements of breaking down. Especially, equipment will be inspected more carefully concerning vibrations, heat generation, leaks, pressures and other significant symptoms for breaking down earlier than expected (Mobley, 2011).

In recent years, remarkable developments have taken place in the maintenance management of the production systems to reduce the wastage of energy and resources. Nowadays, Maintenance is considered an integral part of the business process as it provides added value to the machines and equipment. It is very much essential for any organization to introduce a maintenance management system to improve its quality and productivity (Ramachandra, 2016).

As mention before, not so many years ago, most of the operations of the manufacturing systems were performed with human labour and with less than full capacity, with low productivity and high costs of producing products. The industrial development during the 20th century has brought modern technology with automation and robots and with that, the importance of maintenance functions has increased due to its role in keeping and improving the availability, product quantity, safety requirements, as maintenance costs constitute an important part of the operating budget of manufacturing firms (Al-Najjar and Alsyouf, 2003). This industrial development that can be translated by great evolutions and advancements on information technology, also enabled manufacturing companies to start providing after sales, enabling existing customers to quickly contact the supplier's resources that are needed in order to create satisfactory product-related services or solutions to problems. The high-quality approach of prevention at source was translated to the maintenance environment through the concept of TPM (Kennedy, 2006).

2.3. Total Productive Maintenance

In response to maintenance problems encountered in a manufacturing environment, the Japanese developed the concept of Total Productive Maintenance (TPM), a manufacturing program designed primarily to maximize equipment effectiveness throughout its entire life through the participation and motivation of the entire workforce (Nakajima, 1988).

TPM has been described as a manufacturing strategy including the following steps (Nakajima, 1988):

- Maximizing equipment effectiveness through optimization of equipment availability, performance, efficiency, and product quality;
- Establishing a preventive maintenance strategy for the entire life cycle of equipment;
- Covering all departments such as planning, user and maintenance departments;
- Involving all staff members from top management to shop-floor workers;
- Promoting improved maintenance through small-group autonomous activities.

TPM methodology focuses on eight pillars that are (Nakajima model): Focused Maintenance; Autonomous Maintenance; Preventive Maintenance; Training and Education; Maintenance Prevention; Quality Maintenance; Administrative TPM; Safety and Environment (Pomorski, 2004). These pillars will be explained in more detail further.

2.3.1. The Objectives and Benefits of TPM

TPM is a world-class approach, which involves everyone in the organization, working to increase equipment effectiveness. TPM implementation in an organization can ensure higher productivity, better quality, fewer breakdowns, lower costs and, reliable deliveries, motivating working environments, enhanced safety and improved morale of the employees (Seth and Tripathi, 2005).

According to Nakajima (1988), the objectives of this approach are to:

1) Achieve zero defects, zero breakdowns and zero accidents in all functional areas of the organization;
2) Involve people at all levels of the organization.

The ultimate benefits that can be obtained by implementing TPM are enhanced productivity and profitability of the organizations. TPM aims to increase the availability of existing equipment in each situation, reducing in that way the need for further capital investment. Instrumental to its success is the investment in human resources, which further results in better hardware utilization, higher product quality and reduced labour costs (Bohoris et al., 1995).

Ahuja and Khamba (2008) explained that through strategic TPM implementation is easier to accomplish various organizational manufacturing priorities and goals, observed in Figure 6.

Manufacturing priorities	**TPM considerations**
Productivity (P)	Reduced unplanned stoppages and breakdown improving equipment availability and productivity Provide customization with additional capacity, quick change-over and design of the product
Quality (Q)	Reduce quality problems from unstable production Reduced in-field failures through improved quality Provide customization with additional capacity, quick change-over and design of the product
Cost (C)	Life cycle costing Efficient maintenance procedures Supports volume and mix flexibility Reduced quality and stoppage-related waste
Delivery (D)	Support for JIT efforts with dependable equipment Improves the efficiency of delivery, speed. and reliability Improved line availability of skilled workers
Safety (S)	Improved the workplace environment Realizing zero accidents at workplace Eliminates hazardous situations
Morale (M)	Significant improvement in kaizen and suggestions Increase employees' knowledge of the process and product Improved problem-solving ability Increase in worker skills and knowledge Employee involvement and empowerment

Figure 6 - Organizational manufacturing priorities and goals realized through TPM (Source: Ahuja and Khamba, 2008)

2.3.2. The Eight TPM Pillars

Total Productive Maintenance (TPM) is classified into eight pillars, all of which are supported by 5S include Autonomous Maintenance, Focused Improvement, Planned Maintenance, Quality Maintenance, Education & Training, Office TPM Pillar, Safety Health & Environment and Development Management Pillar (Ireland & Dale, 2001; Shamsuddin et al., 2005).

TPM initiatives, as suggested and promoted by the Japan Institute of Plant Maintenance (JIPM), involve an eight-pillar implementation plan that results in a substantial increase in labour productivity through controlled maintenance, reduction in maintenance costs, and reduced production stoppages and downtimes. The JIPM eight pillar TPM implementation plan is depicted in Figure 7.

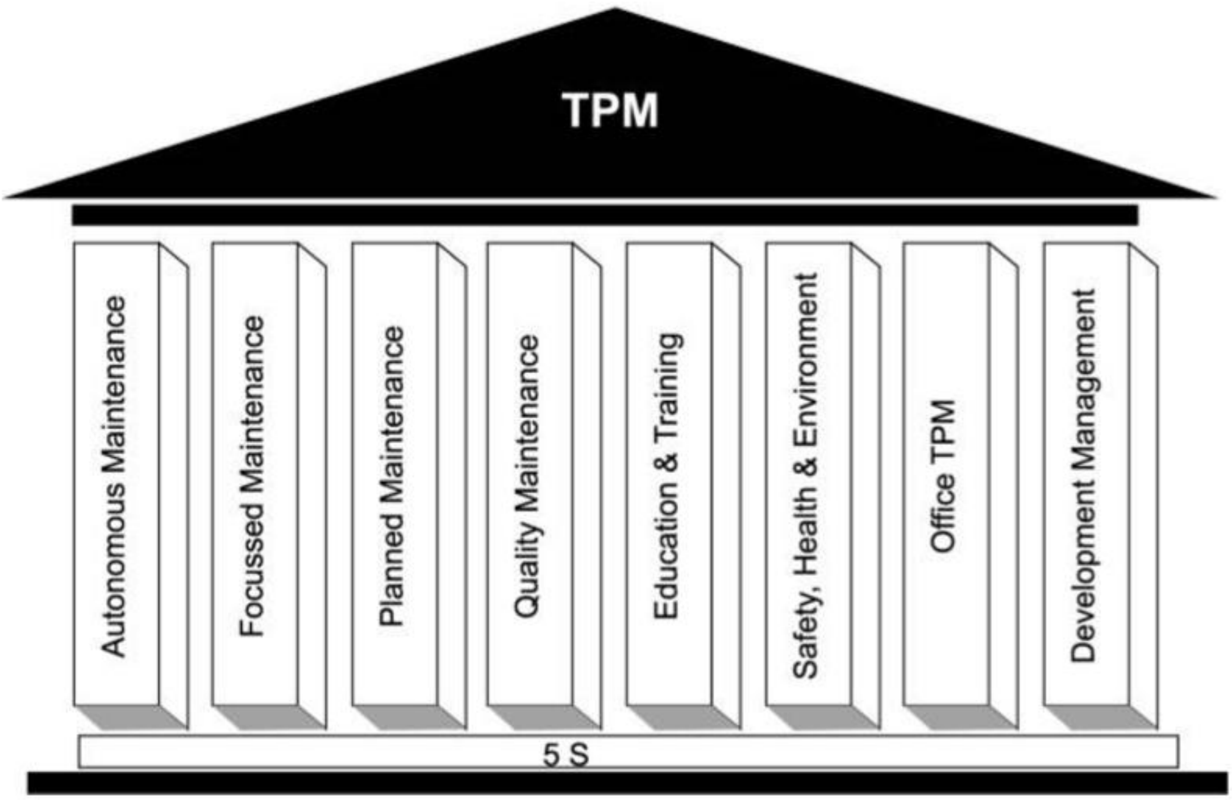

Figure 7 - Eight pillars approach for TPM implementation (Source: JIPM, 1997)

Shamsuddin et al., 2005 have emphasized that to make a manufacturing system efficient, effective, environmentally sound and fair to human society, TPM can be combined with Japanese 5Ss housekeeping rules. The combination of TPM and 5S appears to be appreciable for obtaining a “total” productive environment. There is enough proof that companies have promoted their competitiveness through the applications of total productive maintenance and 5S housekeeping functions (Nakajima, 1988; Willmott, 1994). That is why 5S appears as the foundation for TPM. 5S is a systematic process of housekeeping to achieve a serene environment in the workplace involving the employees with a commitment to sincerely implement and practice housekeeping. Problems cannot be clearly seen when the workplace is unorganized. Cleaning and organizing the workplace helps the team to uncover problems. Making problems visible is the first step to improvement. 5S is the name of a workplace organization method that uses a list of five Japanese words: seiri, seiton, seiso, seiketsu, and shitsuke. There are five primary 5S phases: sort, straighten, shine, standardize, and sustain (Singh et. al., 2013). Refer to the 5S meaning in Figure 8.

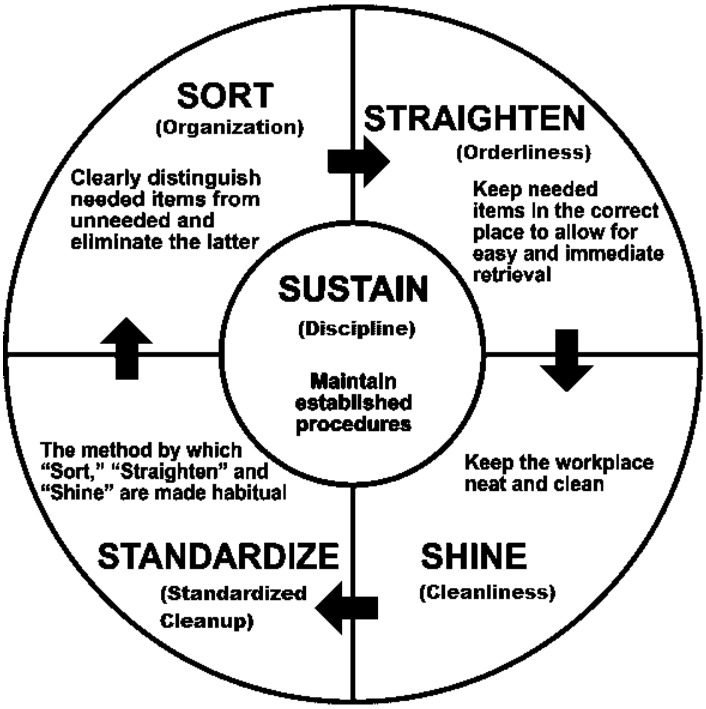

Figure 8 - 5S Meaning (Source: Singh, 2013)

Often the simplest tasks are overlooked which highlights the importance of having 5S always present in any organization. The eight pillars will be explained below and will be used as the link between questions and recommendations in the resolution of this business project. This will be explained in Chapter 4 - Methodology.

Pillar 1: Autonomous Maintenance (Jishu Hozen)

The Japanese name of autonomous maintenance is Jishu Hozen. This activity consists in developing operators to make them 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. Autonomous maintenance involves the participation of every operator, maintaining their equipment and conducting activities to keep it in the proper condition and running correctly (Tajiri and Gotoh, 1992; Robinson and Ginder, 1995). This pillar targets on prevention of equipment deterioration through appropriate operation and daily inspections, restoration and proper management of equipment and establishment of the basic conditions essential to keep the equipment up (Suzuki, 1994).

According to Shirose (1992), Jishu Hozen policies are adopted to:

- Uninterrupted operation of equipment.
- Flexible operators to operate and maintain other equipment.
- Eliminating the defects at source through active employee participation.
- A stepwise implementation of Jishu Hozen activities.

Tajiri and Gotoh (1992) and JIPM (1997) underlined two main aims of autonomous maintenance: cultivate the knowledge and skills in the operators necessary to operate and maintain their equipment; establish an organized shop floor where the operators may easily detect any abnormality.

For that, one-point lessons are therefore a learning method frequently used during daily work, such as during morning meetings or other times. It is highly effective if each individual member thinks, studies, and prepares a genuine one-point lesson and explains its content to all the other circle members, to hold free discussions on the spot and to make the issue more precise (JIPM, 1996). This teaching technique helps people learn a specific skill or concept in a short period of time through the extensive use of visual images. Single-point lessons are effective in transferring the technical skills required for a production operator even for minor maintenance responsibilities (Robinson and Ginder, 1995).

For operator involvement, McKone et al. (1999) use an objective measure of the percentage of operators who are directly involved in the maintenance delivery process. This measure provides the indicator of the implementation level of autonomous maintenance.

Pillar 2: Focused Improvement (Kaisen Kobetsu)

This pillar is aimed at reducing losses in the workplace to improve operational efficiencies (Gulati, 2003). Hence improve OEE, cross-functional teams have the combined necessary skills and knowledge of the entire system of manufacture to identify correctly the practices and activities that relate to the six big losses (Bamber et al., 2003). The use of cross-functional teams for improvement activities improves the problem-solving capabilities of the workers (Adesta et al., 2018). This effective improvement plans can be developed that ensure the best utilization of operational and other resources aimed at improving the manufacturing performance. Henceforth, OEE as an operational measure for manufacturing organizations should be implemented and data gathered, studied and calculated by cross-functional teams that aim to control and effectively improve manufacturing system performance (Bamber et al., 2003).

To assess the level of cross-training, McKone et al. (1999) and other researchers used five questions that relate to the amount of cross-training that is provided and utilized within the plant. The measure evaluates the skills of operators and specifies whether an organization has established an environment where cross-training is possible.

TPM programs have been implemented by many companies and can be adopted by companies in different environments and within various types of organizations. McKone et al. (1999) results indicated that the managerial contextual variables, which are under the jurisdiction of plant management, are more important to the execution of TPM programs than environmental and organizational variables. Logistics and production play a very important role in the success of daily operations. When they are not aligned, production due dates and delivery schedules cannot be fulfilled. (Leflar, 2001).

Kaizen is a Japanese word for improvement. Kaizen’s theory says it is a fact that every employee can improve their work and the method of working (Rajput et al., 2012). So, involving all employees in groups or teams, these pillar objectives are:

- Zero losses (identify and eliminate losses)

The equipment failure is eliminated by exposing and eliminating hidden defects that deliberately interrupt equipment operation before breakdown (Nakajima, 1988; Tajiri and Gotoh, 1992).

- Improve the effectiveness of all equipment

OEE is a key metric of the focused improvement. According to Leflar (2001), focused improvement includes identification, quantification, and elimination of losses that affect productivity, quality, performance, etc. According to Suzuki (1994), focused improvement encompasses all activities that maximize the overall effectiveness of equipment, processes, and plants; also improves the performance through the complete elimination of losses (Pomorski, 2004). The equipment restoration is a prime initial step in focused improvement. Wireman (1991) underlined that during maintenance of equipment tasks like cleaning, lubricating, adjusting, and tightening are neglected (Pomorski, 2004).

Pillar 3: Planned Maintenance

Planned maintenance typically involves the work conducted by highly skilled maintenance technicians. As more tasks are transferred to operators through autonomous maintenance, the maintenance department takes a more proactive approach to maintenance and is able to develop a disciplined planning process for maintenance tasks, such as equipment repair replacement, and on determining countermeasures for equipment design weakness (Nakajima, 1989; Suzuki, 1992).

The objective of Planned Maintenance is to achieve and sustain the availability of machines, optimum maintenance cost, maintainability of machines, zero equipment failure and break down, ensure availability of spares all the time and improve reliability. Reliability is the probability that an asset or item will perform its intended functions for a specific period under stated conditions. It is usually expressed as a percentage and measured by the mean time between failures (Gulati, 2013). Implementing these activities efficiently can reduce input to maintenance tasks, as regular preventive maintenance (periodic maintenance, predictive maintenance) to stop failures; corrective maintenance and daily maintenance prevention to reduce the risk of failure; breakdown maintenance to restore machines to working order as soon as possible after failure; providing guidance and assistance in autonomous maintenance (Suzuki, 1994). According to Mckone et al. (1999), maintenance scheduled using the historical failure rate of equipment Maintenance can be scheduled when production activities are few (Adesta et al., 2018). Planning and Scheduling have the highest potential impact on the timely and effective accomplishment of maintenance work. Although planning and scheduling are closely related, planning is about what and how; scheduling is about when and who (Gulati, 2013).

Improved maintenance procedures such as Reliability Centred Maintenance, Total Productive Maintenance, Root Cause Failure Analysis, and Failure Mode and Effects Analysis have been applied to achieve maintenance objectives: the focus is now shifting to highlight those aspects where the inherent design of the system yields probabilities of failure that are unacceptable and so provide some guidance and motivation for improving the effectiveness of the system (Eti et al., 2006).

When the availability metric is low, it means that the company presents significant breakdowns or changeovers that could be avoided. This can lead to not achieve due to date promises or to fail in fulfil scheduled delivery times. An integrated life-cycle management system in the plant allows identifying the condition of the equipment in real-time. This could allow to detect misfunctions in the equipment and solve them as soon as possible. Typically, planning departments also have good information tracking systems that enable them to capture the process data, gather and disseminate data to operators, and identify trends or problems with equipment (Suzuki, 1992).

Maintenance technicians are held accountable for completing maintenance tasks within a scheduled timeframe while still meeting production requirements. Schedule compliance is an important indicator of the health of the planned maintenance system (Nakajima, 1988).

While both the operators and maintenance personnel are involved in the planning and execution of maintenance within a TPM program, the maintenance personnel are ultimately held accountable for long term maintenance planning and the state of readiness of the equipment. With the available data, these researchers considered three measures of planned maintenance: two perceptual measures for disciplined planning and information tracking, and an objective measure for schedule compliance. A disciplined planning approach typically dedicates time for scheduled maintenance activities, assigns tasks to specific people and inspects for good quality workmanship (Mckone et al., 1999).

Pillar 4: Quality Maintenance

Quality ingrained in the equipment to reduce defects. Defect reduction and consequent profit improvement (Adesta et al., 2018).

This pillar focuses on eliminating product quality related to non-conformances (defective) in a systematic manner. As operators gain an understanding of how various components of the equipment affect product quality, they begin to eliminate the current quality issues and then prepare to tackle potential quality concerns. At this point, operators start making the transition from a reactive to a proactive approach, that is, from quality control to quality assurance (Gulati, 2013).

Poka-Yoke (means mistake-proofing) technique is developed by Shigeo Shingo and Taiichi Ohno by 1961, who also developed the Toyota Production System (TPS) and Just-In-Time (JIT) production system. Poka-Yoke uses devices on process equipment to prevent the special causes that result in defects, or to inexpensively inspect each item that is produced to determine whether it is acceptable or defective. Poka-Yoke designed a manufacturing device is one of the bases of the Zero Quality Control concept which means that the defect rate in a production system is zero. Poka-Yoke design can dramatically decrease the risk of producing defectives again (Tsou and Chen, 2005).

Quality maintenance is achieved by maintaining conditions within specified standards, inspecting and monitoring conditions to eliminate variation, and executing preventive actions before the occurrence of defects or equipment/process failure.

Pillar 5: Education and Training

Bridging of the skills and knowledge gap through training of all workers Employees gain the necessary skills to enable them to solve the problems within the organization (Adesta et al, 2018).

Under this pillar, it is possible to assess technical training needs, determine the current status of skill sets and establish a training plan based on the gap analysis. The goal is to have a multi-skilled workforce, to create a cadre of experts for supporting all aspects of TPM and upgrade the skill set of operators. It is not enough to have only know-how skills; they must also know-why. Appropriate training can improve their skill sets to perform root cause analysis and other tasks required to improve equipment effectiveness and reduce costs (Gulati, 2013).

Pillar 6: Development Management

Design of new equipment using the lesson learned from previous TPM activities. New equipment achieves full potential in a shorter period (Adesta et al, 2018).

The classic objective of Maintenance Prevention (Develop Management) is to minimize the life cycle cost (LCC) of equipment (Pomorski, 2004).

In the development of new equipment, these maintenance initiatives must start at the design stage. Maintenance prevention often roles by learning from earlier equipment failures; product malfunctions; feedback from production areas or new production systems (Jain et al., 2014).

The lessons of successes and failures of TPM activities are incorporated into the design of new equipment and products. The goal is to produce almost perfect equipment and better-quality products by taking care of inefficiencies and safety issues during the design, build, and commissioning processes (Gulati, 2013).

Development Management invoices discovering weak points in the currently used equipment and feeding this information back to the equipment design engineers. It is similar to design for manufacturing (Gulati, 2013).

Maintenance Prevention design considers the following factors: Ease of autonomous maintenance (operator maintenance); Ease of operation; Ease of maintenance -improving maintainability, quality, and safety (Gulati, 2013).

Pillar 7: Office Improvement

The spread of the principles to administrative functions within an organization. Support functions understand the benefits of these improvements (Adesta et al., 2018).

Administrative TPM applies activities to continuously improve the efficiency and effectiveness of logistics and administrative functions since the logistic and support functions have a significant impact on the performance of manufacturing operations. For its effective implementation, TPM must embrace the entire company, including manufacturing support functions, administrative and support departments (Pomorski, 2004).

According to Suzuki (1994), these departments can help raise production-system effectiveness by reducing waste, loss and improving every type of organized activity that supports Manufacturing. (Pomorski, 2004) Implementing Administrative TPM is similar to process related TPM continuous improvement (Sharma, 2012).

Pillar 8: Safety, Health, and Environment

Providing an ideal working environment devoid of accidents and injuries. Elimination of harmful conditions & healthy workforce (Adesta et al., 2018)

Shirose (1996) depicts safety as “the maintenance of the peace of mind”. Safety and environmental considerations are crucial in the global manufacturing era of lean and green manufacturing and it has been given due weight in TPM. No TPM program is meaningful without a strict focus on safety and environmental concerns. Ensuring high equipment reliability, preventing human error, and eliminating accidents and pollution are the objectives of TPM (Suzuki, 1994).

Examples of how TPM improves safety and environmental protection are: Defective or unreliable equipment is a source of hazardous to the operator and the environment. The TPM objective of Zero-failure and Zero-defects directly supports Zero-accidents. Operators accept accountability for safety and environmental protection at their workplaces. Safety and environmental protection norms are proliferating and enforce as part of the TPM quality maintenance pillar.

Green energy is a term used to describe sources of energy that are environmentally friendly and non-polluting, such as geothermal, wind, and solar power. These sources of energy may provide a remedy to the effects of global warming and certain forms of pollution.

Reduce energy consume is another way. Many energy efficiency best practices can be implemented in plant operations such as rearrange plant layout to improve product flow, use right-sized equipment rather the oversized and inefficient one, and incorporate energy reduction best practices into day-to-day autonomous maintenance activities to ensure that equipment and processes run smoothly and efficiently (Gulati, 2013).

According to Gulati (2013), in this pillar, the focus is on the 100% elimination of accidents as well as on employee health and environmental concerns.

The focus is to create a safe workplace and surroundings with the following goals:

- Zero accidents
- Zero health concerns (damage)
- Zero environmental incidents

2.4. Overall Equipment Effectiveness

Recommendations about better use of TPM can be understood as adding value to the customer's current operation once TPM improves the Overall Equipment Effectiveness (OEE) and improving OEE is improving the plant’s efficiency, performance, and production quality. This metric is going to be explained next which will help to understand how the TPM pillars will do the link between the questionnaire and the recommendations, ensuring that they could provide a real added value to customers.

Overall Equipment Effectiveness (OEE) is a key metric used in TPM that provides an overall framework for measuring production efficiency (Gulati, 2013). It is proven the TPM activities improve OEE, as Ireland and Dale (2001) showed studying three implementations of TPM in the UK; as McKone et al. (1999) demonstrated studying ninety-seven implementations of TPM in USA, Japan and Italy, and as Arunraj and Maran (2014) showed studying thirty-three implementations of TPM mainly in India.

The OEE concept is becoming increasingly popular and has been the most widely used quantitative tool for the measurement of productivity (Huang et al., 2003). TPM activities focus on eliminating the six major losses. The objective of OEE is to identify these losses using a bottom-up approach where an integrated workforce strives to achieve OEE by eliminating the Six Big Losses (Jonsson and Lesshammar, 1999). According to Nakajima (1988), the Six Big Losses are:

1) Equipment Failure: It accounts equipment failures/breakdown losses are the time losses and quantity losses caused by defective products;
2) Set-up and Adjustment Losses: These are defined as time losses resulting from downtime and defective products that occur when production of one item ends and the equipment is adjusted to meet the requirements of another item;
3) Idling and Minor Stop Losses: They occur when the production is interrupted by a temporary malfunction or when a machine is idling;
4) Reduced Speed Losses: They are referred to the difference between equipment design speed and actual operating speed;
5) Reduced Yield Losses: They occur during the early stages of production from machine start-up to stabilization;
6) Quality Defects and Reworks: These are losses in quality caused by malfunctioning of production equipment.

The first two losses are known as downtime losses and are used to calculate the availability of a machine. The third and fourth are speed losses that determine performance efficiency. The final two losses are recognized as losses that can happen due to defects in the products. This means that OEE is always measured in terms of the Six Big Losses and that these losses are essentially a function of the availability, performance and quality rate of the machine, production line or factory (Ljungberg, 1998).

In Figure 9, it is possible to observe how OEE is built up. The OEE main factors will be explained in more detail in the next paragraphs, as well as the OEE Six Big Losses.

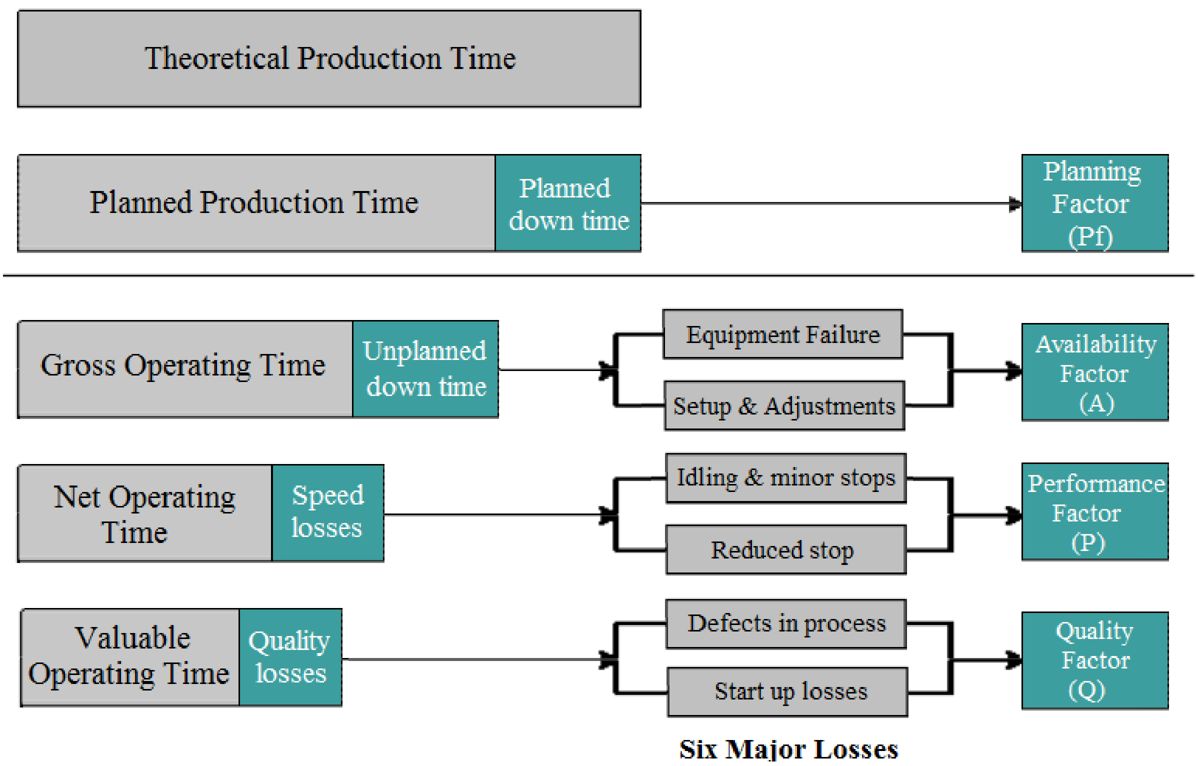

Figure 9 - OEE schematic representation (Source: Wauters and Mathot, 2002)

In the presented figure, Planned Production Time represents the actual time planned for production. The Planned Downtime is defined by planned breaks and its value is subtracted from the Theoretical Production Time. The calculation is presented by:

Planned Production Time = Theoretical Production Time – Planned Downtime

The calculation of the Gross Operation Time describes the total amount of time that a machine is producing, including idling and reduced speed losses, having in mind the knowledge of the Unplanned Downtime that is defined by longer stops unplanned of a machine (more than 5 minutes). The Gross Operation Time is a variable connected with the Availability Factor and its calculation is presented by:

Gross Operating Time = Planned Production Time – Unplanned Downtime

The calculation of the Net Operation Time, that explains the time that is driven to produce the finished items based on the equipment capacity initially designed, includes shorter stops in the

Speed Losses variable. The Net Operation Time is connected to the Performance Factor and its calculation is presented by:

Net Operating Time = Gross Operating Time – Speed Losses

The time that the machine has been producing effectively when Quality Losses are removed from the Net Operating Time is represented by the Valuable Operating Time. This variable is connected to the Quality Factor and its calculation is presented by:

Valuable Operating Time = Net Operating Time – Quality Losses

The calculation of the OEE can be performed in two ways:

$$OEE = Availability\ (A) \times\ Performance\ (P)\ \times Quality\ (Q)$$

$$OEE = \frac{Valuable\ Operating\ Time}{Planned\ Production\ Time}$$

According to Wauters and Mathot (2002), to become world-class with an OEE of 84%, a machine must obtain 99% in the quality factor, 95% in performance and 90% in availability. This means that in order to accomplish a good OEE value, it is essential that all three factors are studied and comprehended:

1) Availability Factor

The Availability Factor (A) represents the amount of time that a machine is available for production, measuring the dimension of the downtime losses. Its calculation is presented by:

$$A = \frac{Gross\ Operation\ Time}{Planned\ Production\ Time}$$

2) Performance Factor

The Performance Factor (P) measures how effective a machine transforms input to output, having in mind that when a machine is not producing it does not always mean that there is a breakdown, it could mean that there is a lack of material or labour. Its calculation is given by:

$$A = \frac{Net\ Operating\ Time}{Gross\ Operation\ Time}$$

3) Quality Factor

The Quality Factor (Q) is defined by the rate of rejected items due to quality defects. The calculation of this factor can be presented by both equations:

$$Q = \frac{Valuable\ Operating\ Time}{Net\ Operating\ Time} \qquad Q = 1 - \frac{Number\ of\ Rejected\ Items\ due\ to\ Quality}{Number\ of\ Produced\ Items}$$

2.5. Literature Review Synthesis

The literature review begins approaching the concept of Servitization as a way to generate value for the company and its customers. In the specific case of this business project, the way to create value by Servitization is through the development of recommendations to customers for them to overcome their plant failures highlighted by the results of the ACV-Fingerprint questionnaire. In his way, the company can also start providing services to their customers, by connecting the recommendations with potential products and services, increasing their loyalty and confidence levels. In order to develop specific recommendations connected to possible questionnaire results, the TPM philosophy had to be studied since this philosophy gathers all the fundamental topics of what questions might be intended to access. In this sense, the analysis of the eight TPM pillars should be conducted and it should be created a link to each topic of ACV-Fingerprint questions. Some of the topics that the ACV-Fingerprint might contain are Availability, Performance and, Quality and this is another reason why TPM philosophy was the chosen one to be the centre of this study: the OEE metric was developed by this philosophy and its preferred calculation is based on the three OEE Factors: Availability, Performance, and Quality. This metric intends to provide a very valuable outcome of how effectively some manufacturing process is running («as is» stage) which makes it easy to track improvements in that process over time («as it should be» stage). What the OEE score does not provide is any insights into the underlying causes of lack of productivity. To have these insights, the calculation of the three factors of Availability, Performance, and Quality must be done. As previously outlined in the literature review, there are different formulas to calculate the OEE metric. In order to obtain not only information regarding how the manufacturing plan is performing but also be able to capture the fundamental nature of its losses, the formula that must be used is the one that consists in the multiplication of the three factors.

These three topics, which were mentioned in the literature review, are the key to achieve the goal of this business project that consists in creating value to both the company and its customers by developing recommendations that not only enable customers to understand and overcome their plant failures but also allow the company to offer a broader more adequate solution that better adjusts to the needs.

3. Conceptual Framework

3.1. Propositions Formulation

After the literature review, the most relevant topics will emerge and will enable the formulation of the main propositions that will support the Conceptual Framework (Figure 10).

According to Cooper and Schindler (1998), the research literature disagrees about the meaning of the terms proposition and hypothesis. A proposition is a statement about the concepts that may be discussed if it refers to observable phenomena. Hypotheses should be confirmed or not on a yes/no quantitative base.

In this business project, it was chosen to use propositions due to its qualitative nature. So, after developing the literature review, the propositions that have emerged from the literature are, as follows:

P1. *"Servitization is a way to generate value to the company and its customers (vide sections 1.1.1 and 2.1)".*

P2. *"The ACV-Fingerprint questionnaire identifies the main potential failures of the customers (vide section 1.1.2). The development of recommendations supported by TPM enabled customers to overcome their plant failures (vide sections 1.2 and 2.3.2)".*

P3. *"The generation of recommendations to overcome possible identified customers' plant failures, could allow providing new services supported by these recommendations" (vide sections 1.2 and 2.2)".*

P4. *"Total Productive Maintenance philosophy is an appropriate concept to use as a basis on the recommendations' generation (vide section 2.3.1)".*

P5. *"Services on the automation sector are not the core business. However, they can lead towards competitive advantage and increase the OEE metric value (vide sections 1.1.3 and 2.4)".*

3.2. Graphical Representation of the Conceptual Framework

The conceptual framework development allows researchers to define the concept, map research and synthesize the relevant aspects that emerged from the literature review in a schematic manner (Rocco and Plakhotnik, 2009). In this context, based on the above propositions that synthesises the most relevant concepts regarding the development of the Customer Compass model, the Conceptual Framework presented in Figure 10 was created. The framework connects the ACV-Fingerprint questionnaire (*vide section 1.1.2*) with the Customer Compass model (*vide section 1.2*) in order to identify possible services focused on customer failures, enabling the achievement of the Servitization dimension. By highlighting critical areas of the customers' plants, the results of ACV-Fingerprint questionnaire provide information regarding the main customers' plant failures, that together with the knowledge provided by the TPM philosophy studied, enables the Customer Compass model to generate recommendations to overcome those failures, by following the Root Cause Analysis methodology (***P2***). TPM is used as basis for the development of these recommendations since this philosophy is classified into eight structural pillars that when implemented can lead to a substantial increase in labour productivity (*vide section 2.3*) (***P4***). By being able to understand which are that main potential failures in customers' plants and understand which are the most urgent actions that customers need to take in their plants led by the recommendations, the company is able to start offering new solutions through the development of services, helping customers to improve their plant's performance (***P3***). Following the relevant trend in the manufacturing industry that represents a shift in paradigm, by focusing not only on the production of goods, but offering an integrated package of goods and services, appears to be able to generate value for the specific case of the company under study, since it would be able to achieve a better level of sales and become more competitive in the market by adding services to its offer as part of a differentiation strategy. To the customer's current operation, the generated recommendations also generates value due to the fact that TPM implementation has the power to increase the Overall Equipment Effectiveness (OEE) metric value of a plant, which is translated by an increase of their plant's efficiency, performance, and production quality levels (*vide section 2.4*) (***P5***). Both the ACV-Fingerprint and the Customer Compass model will work together to enable the company to achieve the Servitization dimension which plays a crucial role on value generation process for both, the company and its customers (*vide section 2.1*) (***P1***).

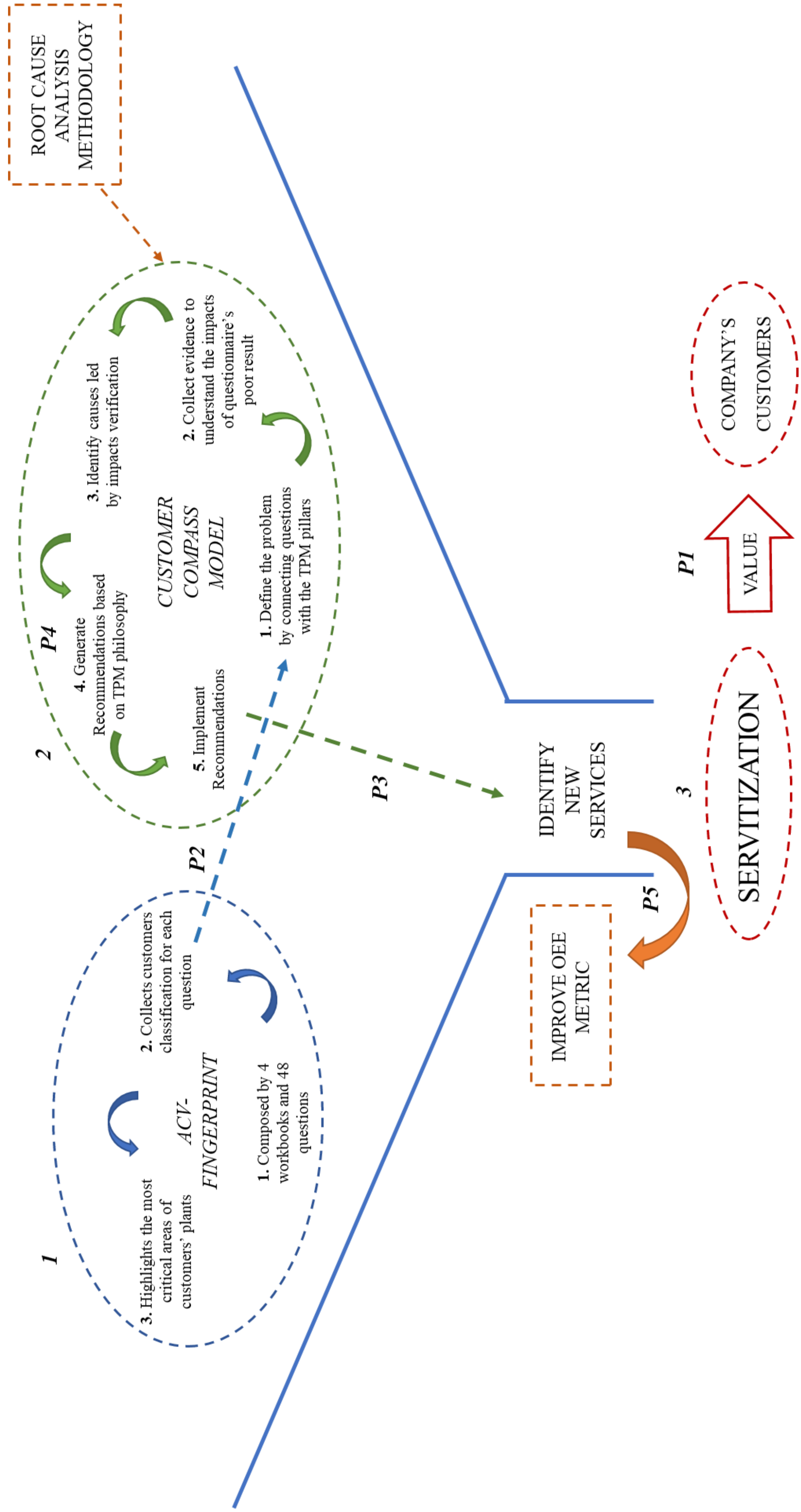

Figure 10 - Conceptual Framework

4. Methodology

4.1. Introduction

The methodology of the business project intends to describe and explain how the research is conducted, highlighting the methods and strategies that are used to answer the research questions.

4.1.1. Research Method and Strategy

The main goal of this business project is to find a supported solution for the company to increase the value proposition to its customers by using the results of the questionnaire and create recommendations to customers to improve their potential plant failures that could be identified. To achieve this goal, the qualitative approach was used. According to Godoy (1995), in a qualitative approach, the emphasis is placed on the whole process and not only on the results. Bryman and Bell (2015) also pointed out that the essence of this type of research is that it provides a complete and detailed description of research, is subjective and provides the main characteristics of events and phenomena in their natural context.

Yin (2009) claims that it is possible to classify the case study typology into three major groups: exploratory, descriptive and explanatory. This business project is an exploratory study, which according to Saunders et al. (2009) aims to clarify the understanding of a particular phenomenon or problem whose nature may not be clear and provide greater knowledge of the problem, aiming to make it more explicit.

Thus, it is essential to define the strategy that best fits the type and method of the project in question. Several research strategies allow the study to be conducted to meet the research questions and achieve the main goal. It is necessary to choose whether the study will be conducted through an essay, a case study or through the application of a survey (Saunders et al., 2009).

For the accomplishment of this business problem, the strategy of the case study was chosen. A case study aims to retain the holistic and meaningful characteristics of real-life events such as the behaviours of individuals and organizations or the management processes and organizational processes (Saunders et al., 2009). According to Yin (2009), one of the decisions that have to be made when conducting a case study is related to its design. Therefore, it is essential to determine whether it will be performed in a single case study or use the multiple case study method. Yin (2009) and Saunders et al. (2009) argue that a single case study can be useful when it is representative, typical, or provides an opportunity to study a particular event, industry or business. Being the procedures of this business project conducted to a particular company context, a single case study will be performed.

4.1.2. Systematic Literature Review

To carry out this business project, a thorough literature review was made regarding the topic of Servitization, Total Productive Maintenance, and Overall Equipment Effectiveness (*vide chapter 0*). According to Boland et al. (2014), the Systematic Review is designed to locate, evaluate, and synthesize the best evidence related to a specific research question or topic to provide evidence-based answers. Therefore, after gathering all the information, propositions containing the most relevant research evidence were formulated (*vide section 3.1*) and the Conceptual Framework was constructed which synthesizes, together with propositions, the main outcomes obtained throughout the literature review (*vide section 3.2*).

4.2. Business Problem Approach

This chapter consists in explaining how to respond to the research questions previously formulated. Collecting the proper data that will enable adequate processing and further analysis of the results corresponds to the main operationalisation of the methodological process. The subsection is structured following the guidance provided by the research questions.

1) **How to develop recommendations that add value to both the company and its customers based on the ACV-Fingerprint result?**

To understand how recommendations could be generated through the ACV-Fingerprint results first, it is important to explain how this questionnaire was formulated.

The ACV-Fingerprint questionnaire (*vide Appendix 1*) supports a customer care conversation between a company salesperson and a customer manager where customers receive an individual assessment-score, based on their answer-rates. It consists in a questionnaire with around 50 questions. The customer answers the questions and the company representative scores these answers using a “choice” based on a scale from 1 to 6. A “choice” consists on the perspective of the company salesperson regarding the comparison between the customer’s answer and the pre-defined scale. This procedure is repeated for all questions of the questionnaire and questions are structured into a few workbooks, which consider different fields of interests that can be observed in Figure 11.

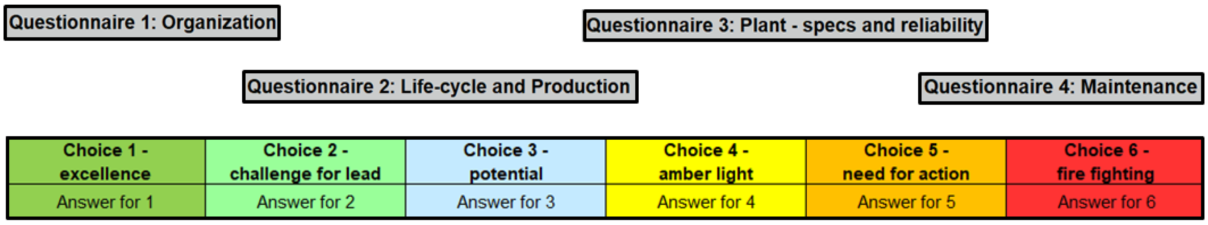

Figure 11 - Workbooks and answer's rates of the ACV-Fingerprint

After answering the questions, the assessment tool calculates the individual score for the customer. To calculate the score, every question is allocated to one or more focus areas and a radar-chart is generated where it is possible to observe the score of the customers in seven parameters *(vide Figure 2*). This will help customers to access information about their plant needs and have a comparison of their results with the best practices in the industry.

The ACV-Fingerprint procedures are presented in the following Use-case Diagram (Figure 12).

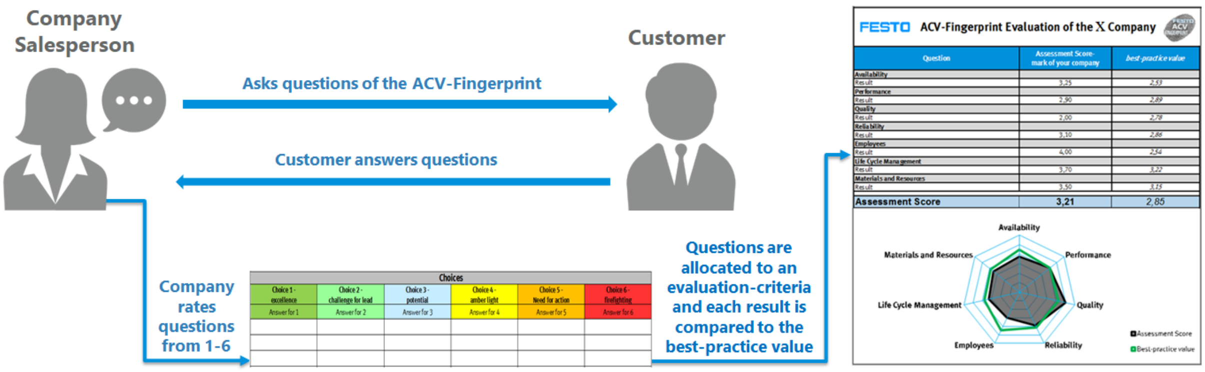

Figure 12 - ACV-Fingerprint procedures

To guarantee that the development of recommendations was updated and aligned with the company strategy, focus group sessions with the duration of one hour each were performed twice a month during the business project development. Morgan (1996) defines focus groups as a research technique of data collection through group interaction about a topic presented by the researcher. Such a definition, according to the author, has three essential components: focus groups are a method of research aimed at data collection, finds interaction in the discussion of the group as the source of the data, and recognizes the active role of the researcher in streamlining group discussion for data collection purposes. These focus groups were performed with the Head of the Future Concepts Department and a Product Manager who was responsible for the service development of the process automation. Notes were taken in order to record the information and after them, transcriptions were carried out.

Focus groups resulted in the idea of grouping questions by the Total Productive Maintenance pillar. The TPM methodology was chosen because of three main reasons: First is the fact that TPM improves OEE (Availiability × Performance × Quality) and the ACV-Fingerprint questionnaire was created to obtain information regarding availability, performance, quality, reliability, employees, life-cycle management and raw materials and resources. The second is that according to Moore (2002), OEE is also a key indicator of reliability and operational performance. Moreover, the third reason is that the same author also refers that reliability and safety are increasingly interrelated being safety treated as the most important attribute in reliability analysis (Gulati, 2013).

Questions were connected to the TPM pillars by using A*ffinity Diagrams*. These diagrams are used to organize ideas, data, facts, opinions and, issues when a problem is complex since they are great tools for assimilating and understanding large amounts of information and link collective thoughts into a clear and understandable structure in order to discover all the hidden linkages (Gulati, 2013).

2) **Which methodology could be used to help structure problem resolution?**

The problem provided by the company was addressed by finding recommendations to customers according to the ACV-Fingerprint questionnaire.

To do this, it was chosen the Root Cause Analysis methodology (RCA) to treat and analyse the data. Since this tool consists in a step-by-step process that leads to discover the prime cause of a failure according to Gulati (2013), it provides a structured way to obtain the causes and impacts for the different ACV-Fingerprint results. Gulati (2013), in his book Maintenance and Reliability Best Practices, explains that the process of performing an RCA is divided into six main steps, depicted in Figure 13.

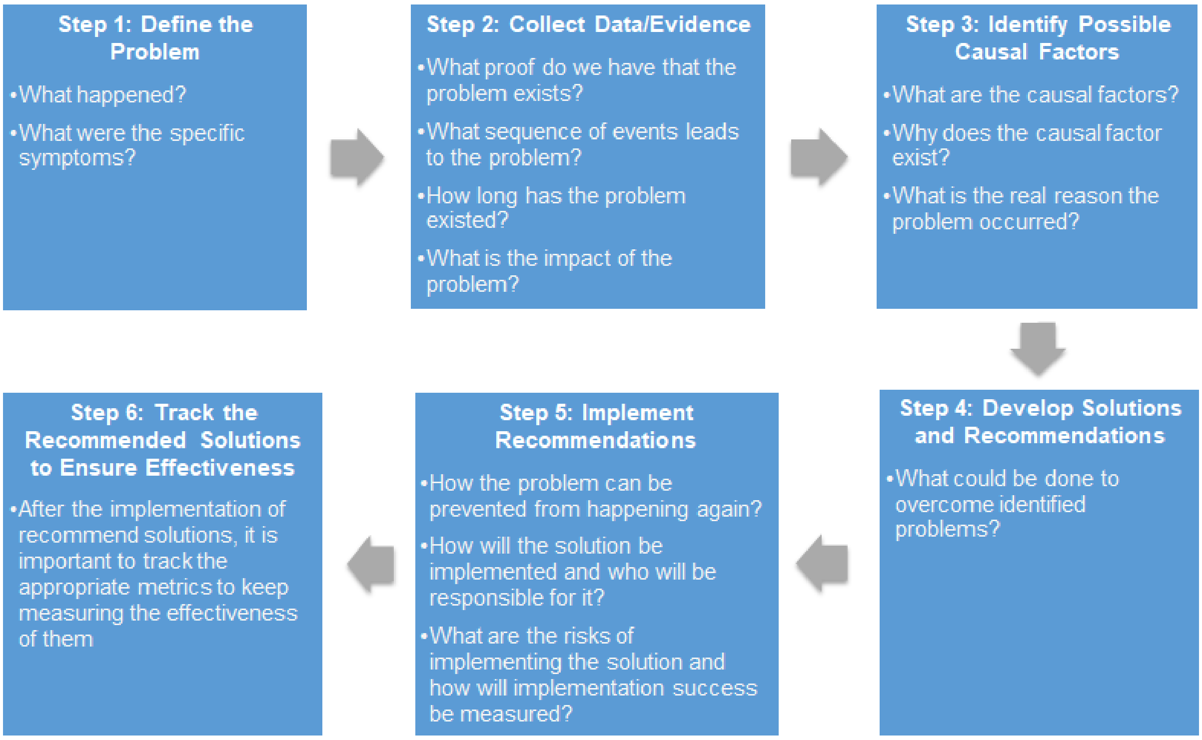

Figure 13 - RCA Process (Source: "Maintenance and Reliability Best Practices" Gulati, 2013) (Adapted)

3) **How to understand the causes and impacts of the questions provided by the ACV-Fingerprint tool?**

Several tools can help to identify causal factors following the RCA methodology. Tools as *Five Whys*, *Cause and Effect Diagrams* and *Drill Down* are designed to encourage analysing deeper at each level of cause-effect. The idea of performing the *Five Whys Technique* is to go behind the symptoms and discover sources for the problem to happen. Brainstorming activities are a key factor to evaluate every possible option and cause for the problem. The *Cause-and-Effect Diagram* is one of the most popular ways in the problem-solving process. This diagram is also called as a *Fishbone Diagram* or *Ishikawa Diagram* and this was the tool chosen. The *Cause-and-Effect Diagram* was created by Ishikawa (1990) and identifies the most likely causes to happen in order to help the improvement team that will focus on the most highlighted cause in order to prevent it from happening. It is used for a cause and effect analysis to identify a complex interplay of causes for a specific problem or event (Coccia, 2017). A graphical representation of the *Cause-and-Effect Diagram* is presented in Figure 14.

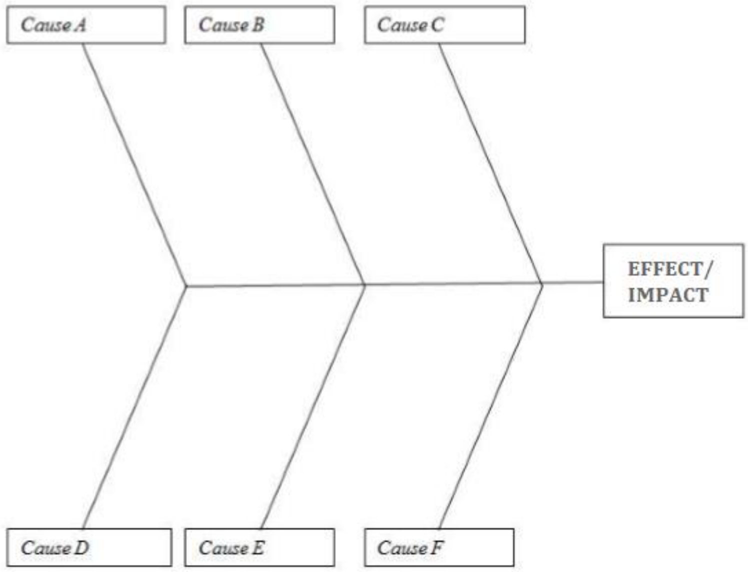

Figure 14 - Cause-and-Effect Diagram (Source: Coccia, 2017)

4) **Which recommendations could be developed to overcome the impacts obtained?**

By developing impacts and finding causes linked to the ACV-Fingerprint questions using the TPM methodology, it was easier to find recommendations. Being this the main goal of this business project, all the procedures were with the final objective of developing recommendations to improve the customers' plants.

4.3. Application of Root Cause Analysis

As mentioned in the previous section, the methodology chosen was the Root Cause Analysis (*vide Figure 13*). To explain how results were analysed, the Root Cause Analysis will be detailed step-by-step:

Step 1. Define the problem

This step consists on finding what happened and what were the specific symptoms of the problem. So, the main objective of this business project was to develop a model that would be able to offer concrete recommendations to the result of the ACV-Fingerprint questionnaire already explained.

This questionnaire, that contains forty-eight questions, had the objective to access customers' plants in different topics. However, the company did not have developed any link to the results obtained in order to offer recommendations to customers and, this way, improve their plants' performance. So, the main request of the company was for the author to find a way to obtain the necessary knowledge to overcome this lack of data. For that, it was developed the Customer Compass Process that is defined in Figure 15.

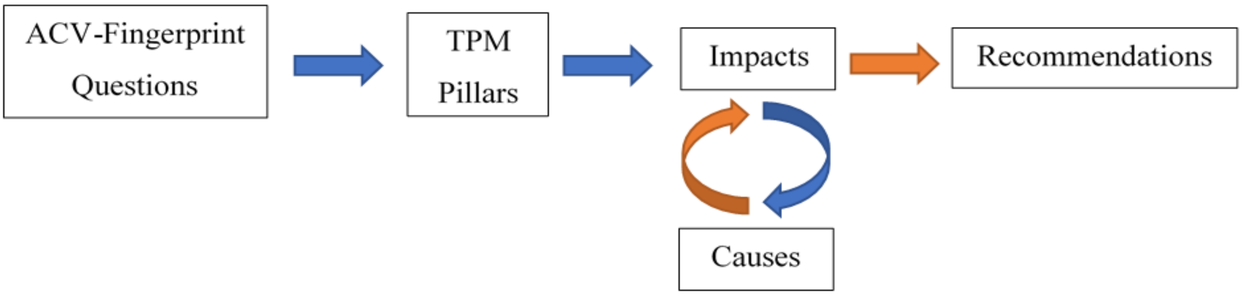

Figure 15 - Customer Compass Model Process

In this process, the ACV-Fingerprint questionnaire is the input, meaning that the ACV-Fingerprint questions were the first thing to be analysed since they were provided by the company alongside with the problem to solve. Questions were rated from 1 to 6, as it was explained before, and the reason for bad results in the questionnaire was the study that needed to be done. This study will lead the author to achieve the output of the process which is the development of recommendations to the customers' plants. This will be possible by following the steps of the Root Cause Analysis methodology in order to analyse the process data. So, to solve this problem, the connection between the questions and the recommendations had to be found, which is explained in Step 2.

Step 2. Collect Data/Evidence

Determine all impacts through the connection of the TPM Pillars and ACV-Fingerprint questions

This step is the first part of the Customer Compass processed that was developed (Figure 16).

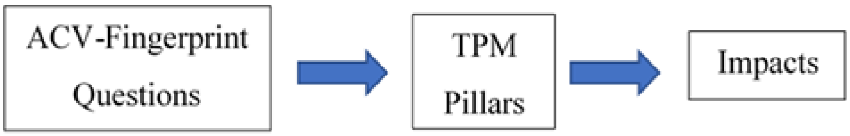

Figure 16 - Customer Compass Model Process (Step 2: Collect Data/Evidence)

In this step, it was important to understand which impacts could arise from a bad result of the ACV-Fingerprint questionnaire. For that, a collection of data and pieces of evidence is essential to obtain knowledge to develop impacts for bad rates in the questionnaire. Knowing this, first, it was collected data from the literature review about Total Productive Maintenance Pillars in order to find a connection between TPM Pillars and ACV-Fingerprint questions. The reason for choosing TPM methodology was already explained in section 4.2 - Business Problem Approach.

To group questions by TPM pillars, focus groups were performed with two employees of the company. This helped the understanding of the logic behind the questions and avoid a loss of traceability to the work previously done.

So, it was important to know that in the ACV-Fingerprint questionnaire all questions were grouped by four workbooks (Organization, Lifecycle and Production, Plant-specs and Reliability, and Maintenance) and seven parameters (Availability, Performance, Quality, Reliability, Employees, Lifecycle management, and Materials and resources) in order to generate the radar-chart that would help customers to access information about their plant's needs. The goal was that with these focus groups, it would be possible to understand exactly what the knowledge behind the questions was.

Analysing the questions, it was understood that these questions had a generic character since they were developed to fit customers of different companies and industries. Thus, it was expected that impacts would be fewer than the questions since the logic would be that several questions with a low average grade evidenced a negative impact that would justify the reason for the recommendation. With this in mind, it was created the first rule: A question is insufficient itself to make an impact and it is responsible for only one impact.

Therefore, conditions were created to start grouping questions by the TPM pillar to generate an impact. To do this, the tool used was the Affinity Diagram.

According to Gulati (2013), *Affinity Diagrams* represent an excellent tool both to group ideas in a logical way and to capture themes that had been developed during brainstorming. The way to create an Affinity Diagram is demonstrated in Figure 17.

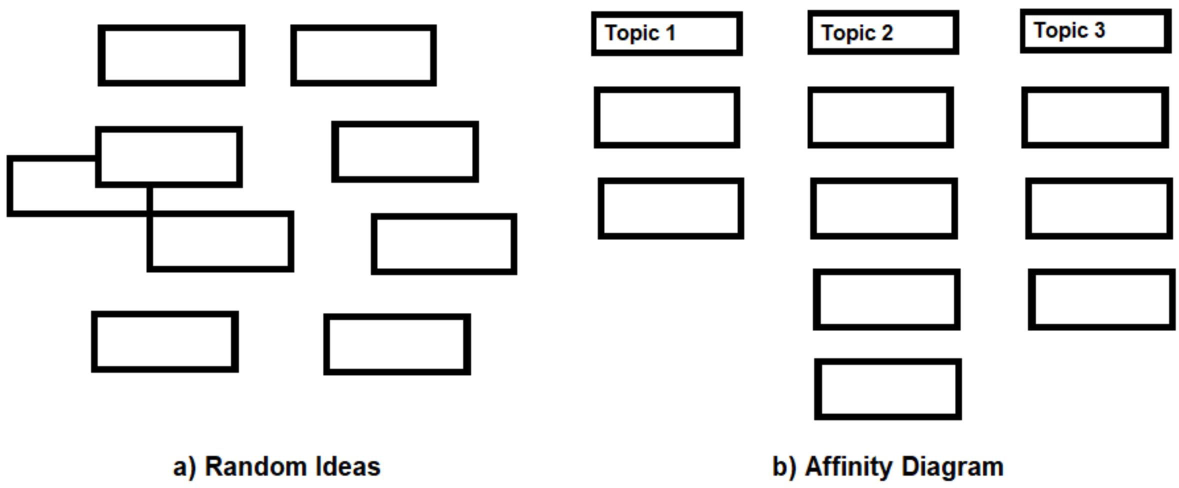

Figure 17 - Preparing an Affinity Diagram (Source: Gulati, 2013)

Creating the *Affinity Diagram*

The creation of the *Affinity Diagrams* was divided into two parts.

1) This procedure started by recording the ACV-Fingerprint questions on post-it notes in order to group them in pairs and triplets, considering their workbook of the ACV-Fingerprint questionnaire (*vide Figure 11*). The ones that were in the same workbook, were grouped together. Then, the eight TPM pillars (*vide Figure 7*) were also represented on post-it notes and a connection between them and the previously defined groups was made. To do this, and considering the TPM methodology, some strategies were defined:

- Groups related to topics of Quality and Safety were linked to their respective pillars (Quality Maintenance and Safety, Health and Environment pillars);
- Groups related to maintenance and lifecycle management were grouped accordingly to Planned Maintenance and Development Management TPM pillars;
- Groups of questions related to the raw materials and resources topics such as deliveries or supply chain were grouped into the TPM Office pillar;
- Questions related to the employees were grouped accordingly into the Focused Improvement, Training and Autonomous Maintenance pillars.

The goal of this first part was to aggregate the questions by the TPM pillars.

2) The second part of the *Affinity Diagram* development was the creation of subgroups by impacts. By collecting evidence in the literature review of the TPM philosophy it was possible to identify which questions of the same group would lead to the same impact and with this create subgroups where the impacts were recorded.

The result of the two parts of this creation of *Affinity Diagrams* was eighteen impacts for eighteen groups of questions (*vide Appendix 2*).

Step 3. Identify Possible Causal Factors

This step of the RCA methodology consists in the study of the reasons for the problems that were determined before to occur. To do this, it had to be identified which causes could lead to the negative impacts that were found in the previous step. This will be the second part of the Customer Compass Process (Figure 18).

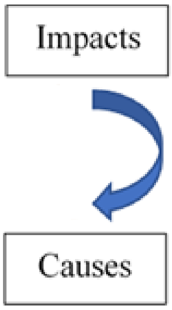

Figure 18 - Customer Compass Model Process (Step 3: Identify Possible Causal Factors)

To find the causes, it was decided to use the fishbone diagram that consists in a tool for identifying the root causes of failures and provides a systematic way of looking at effects and the causes that create or contribute to those effects. Because of the function of the fishbone diagram, it may be also referred to as a cause-and-effect diagram (Watson, 2004).

Step 4. Develop Solutions and Recommendations

This step of the RCA methodology consists in finding what could be done to overcome the problems previously defined, using the *Cause-and-Effect Diagram* (Figure 19). This is the third part of the Customer Compass Process.

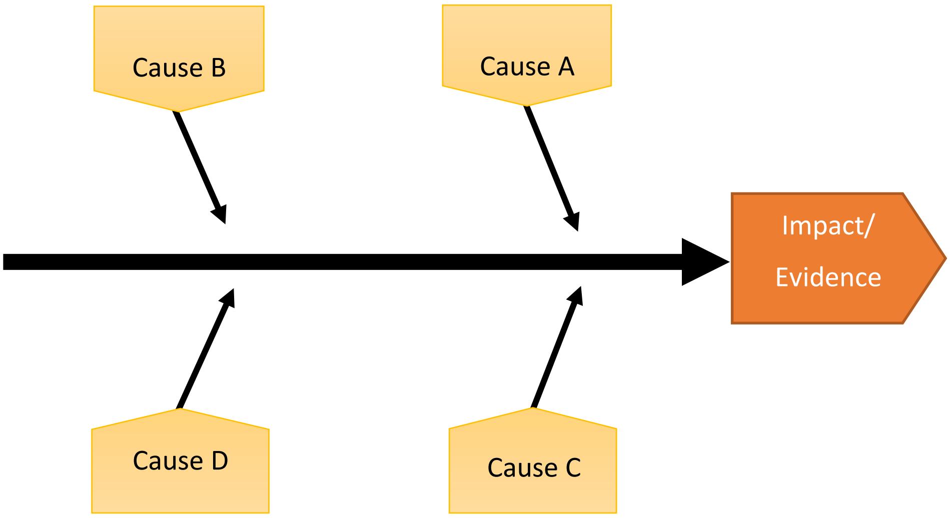

Figure 19 - Cause-and-Effect Diagram example

Development of recommendations

The development of recommendations to improve the customers' plants was according to the literature best practices. Since the match of questions with TPM pillars was previously performed and it was already found impacts and causes of the problems, recommendations will be developed using the TPM philosophy and will be linked to the impacts of the problems (Figure 20).

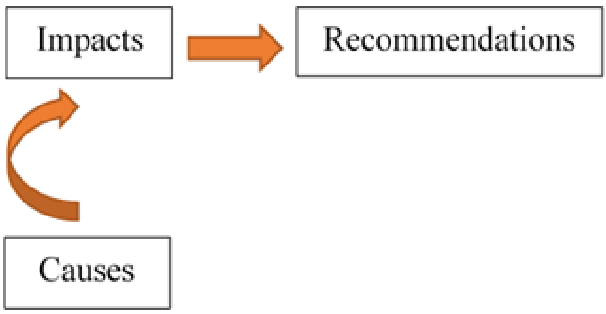

Figure 20 - Customer Compass Model Process (Step 4: Develop Solutions and Recommendations)

According to Gulati (2013), RCA investigates all types of causes. It also involves investigating patterns of negative effects, finding hidden flaws in the system and discovering specific actions that contributed to the problem.

To have an overview regarding the relationship between the Customer Compass and the ACV-Fingerprint, in Figure 21 it is possible to observe the process that aggregates all the activities associated with each one of them.

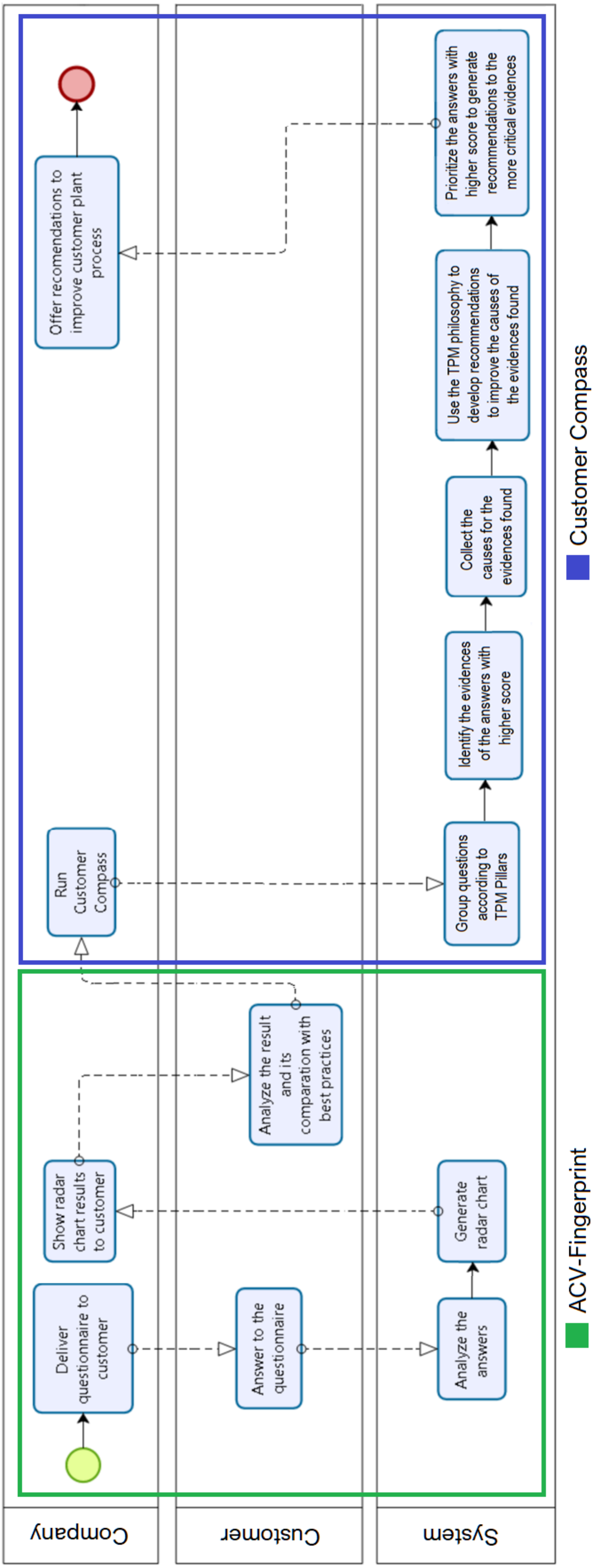

Figure 21 - ACV-Fingerprint and Customer Compass Process

Step 5. Implement Recommendations

In this step, the goal is to connect the recommendations developed in this project to potential services that could be provided by the company in the future. With this, recommendations could be implemented by customers, based on the available services provided by the company. As the company does not provide these services to customers yet and the reason for developing this business project arises precisely from the fact that the company wanted to understand what were the customers' needs and how could add value to their activity by providing services, this stage is to be completed in the future. The goal is that in future recommendations could be implemented in the customers' firms and provide them a type of service tailored to their needs. Nevertheless, a study of potential services that the company could provide based on the recommendations was conducted.

Tukker and Van Halen (2003) affirm that on service-oriented business models firms will have an incentive to prolong the service life of products, to ensure they are used as intensively as possible, to make them as cost- and material-efficiently as possible, and to re-use parts as far as possible after the end of the product's life. Usually, products and machine equipment require different kind of services as they advance through their life cycle (acquisition, installation, operation, upgrades, decommission, maintenance, spare parts, etc.). The expansion of service offerings in successful practice companies starts with product-related services and continues with services directly supporting the customer. The main goal of product-related services is to ensure the proper functioning of the supplier's product (documentation, inspection, repair, maintenance, spare parts, etc.) (Gebauer et al., 2006). In contrast, by offering services supporting customers' actions, suppliers explore how services support particular customer initiatives and advance the mission of customer organization (Mathieu, 2001). Extending the service offerings by starting with product-related services and continuing with services directly supporting the customer, represents the second success factor in increasing service revenue (Oliva and Kallenberg, 2003).

Transposing this idea into the specific context of the company and the automation sector, there are several potential services that the company can introduce in the future. An overview of the main services offered in the automation sector aligned with the company service strategy can be found in Figure 22.

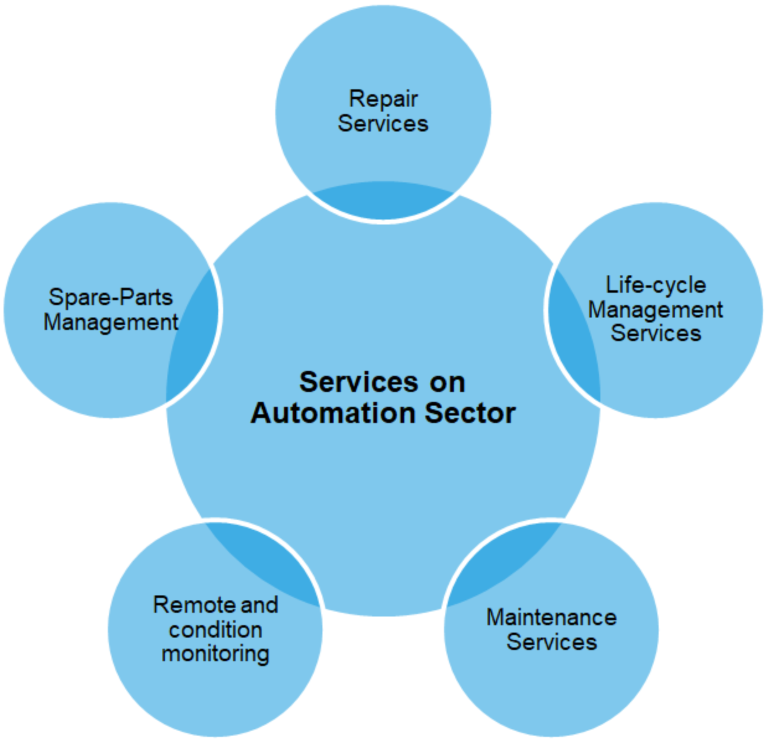

Figure 22 - Main Services on Automation Sector (Source: Company)

1) **Maintenance Services**

The contributions related to maintenance services include component monitoring, diagnostics, prognostics, equipment repair, regular inspection, refurbishment, strategy optimization and health management (Iung and Levrat, 2014).

There were exposed before the different maintenance types available (*vide section 2.2*). The company could suggest the customer adopt a predictive maintenance method that is a more condition-based technique. Condition monitoring displays several physical variables such as temperature, vibrations, use, lubrication conditions, and other parameters It consists in a software tool that evaluates these parameters and calculates an average future lifetime. Further, the software combines experience and real-time conditions to plan the perfect time to maintain the plant operating as it should be.

2) **Spare-parts Management**

Spare-parts management considers the whole process from ordering, processing, and delivery. Spare-parts warehouses for maintenance depend directly on the maintenance strategy. They are characterized by low plan-ability, high provision for risks, a very wide range of parts, changing requirements in terms of quantities, low turnover rate and high requirements in terms of availability. The main goals of a spare-parts management system are to deliver the correct spare part, with correct quantity and type, at the right time, to the right place and with optimum inventories.

3) **Repair services**

Sometimes it is cheaper to repair components than replacing them. This is preferably applied to larger and more expensive components. The key benefit is that the repair reduces the Total Cost of Ownership. Repair services are often used in planned breakdowns. The service representative comes at the agreed time and repairs the affected component quickly and reliably.

4) **Remote & condition monitoring**

Remote and Condition monitoring is a service offer that considers the diagnostic of the monitoring of a condition of a component. This monitoring while the production is running consists in a technology requirement for the product, which only a few have implemented. For condition monitoring, machines need different sensors installed. Further, a remote system has to transfer data to the control system which means that these specs have to be implemented to introduce this service in the company.

5) **Life-cycle management service**

Life-cycle management service manages the entire lifecycle of a component and solutions to guarantee efficient maintenance activities. With this type of service, the customer is provided with a powerful tool and a knowledge base to optimize and extend the lifecycle of equipment. The usability and efficiency of customer's equipment and systems are considering increasing productivity. The life cycle management also can show the status of products' performance, which are no longer being maintained and supported by the manufacturer. This service combines all above-listed services, so the customer is served in the best way possible.

Step 6. Track the Recommended Solutions to Ensure Effectiveness

This step is out of the scope of this business process and it is integrated on the suggestions to future work (*vide section 6.4*). It will consist on tracking the appropriate metrics to keep measuring the effectiveness of recommendations after the implementation of them.

5. Analysis and Preliminary Appreciation of the Results

To test the Customer Compass model, it was decided to use the ACV-Fingerprint results of a real customer of the company. With this information, it was possible to understand if recommendations were adjusted to the customer's plant failures found in the questionnaire and if they fit into reality. Thus, after the evaluation of the customer's answers connected with the TPM pillars, the ones with the worse rate were selected to generate three recommendations following the Root Cause Analysis methodology. The reasoning of the process is explained, as follows.

Step 1. Define the problem

All questions of the ACV-Fingerprint were already grouped by TPM pillars as previously explained (*vide Appendix 1Appendix 1*). In order to identify the problem, questions with the worse rate in the ACV-Fingerprint result were selected and the TPM pillar associated was chosen to be analysed.

The first pillar to be analysed is Focus Improvement. The group of two questions with worse results was:

- "How often should round trips occur in the plant?"
- "How many ideas for improvement do you receive per ten employees per year?"

This TM pillar is aimed at reducing losses in the workplace to improve operational efficiencies (Gulati, 2003). The goal of Kaizen is a continuous improvement process involving everyone, managers and workers alike (Imai, 1989). It is based, mainly, on a culture change to encourage operators' suggestions at their ongoing effort to improve activities or participate in. Shingo (1985) suggests interviewing shop floor staff, while doing frequent round trips in the plant, in order to collect different ideas for improvement.

The second pillar is the Quality Maintenance and the group of questions with worse score was:

- "According to the criticality level of equipment, how do you monitored them in order to prevent consequences in production?"
- "Does the company have its own risk management system? How reliable is it?"
- "Do you have deviations regarding production output or quality?"

This pillar focuses on eliminate quality products' issues related to non-conformances (defective) systematically. As operators gain an understanding of how various components of the equipment affect product quality, they begin to eliminate the current quality issues and then prepare to tackle potential quality concerns. At this point, operators start making the transition from a reactive to a proactive approach, that is, from quality control to quality assurance (Gulati, 2013).

The third pillar is the Autonomous Maintenance and the group of questions with the worse result was:

- "What is the percentage of employees that are performing maintenance and service activities? (outsourcing included)"
- "What is your maintenance staff level of understanding the equipment? How accurate are them predicting deviations or abnormal performance of the equipment?"

According to Gulati (2013), implementing autonomous maintenance requires not only a change in organisation culture, but also a heavy investment in training. Operators who have always said "that's not my job – call maintenance", must now acquire a sense of ownership. They must also acquire the skills to properly implement their new accountability. Operators must now keep the equipment clean, lubricated and secure. Minor repairs and adjustments also become part of operators' responsibility. Operators need to be trained to inspect, measure and continuously diagnose and fix problems.

Step 2. Collect Data/Evidence

Determine the impacts through the connection of the TPM Pillars and ACV-Fingerprint questions

Using the *Affinity Diagram*, it was possible to group the ideas in a logical way and capture what has been developed during the brainstorming to identify which impacts could arise from the customers' answers with worse results.

- The impact that arose from the pillar Focus Improvement based on the answers of the questions presented before was: The organization do not obtain the key vision of operators that play a central role in the process what could turn the company incapacitated to detect some issue in the process before it harms the entire process.

To obtain a better understanding of the visual effect of this *Affinity Diagram*, its illustration is possible to observe in Figure 23.

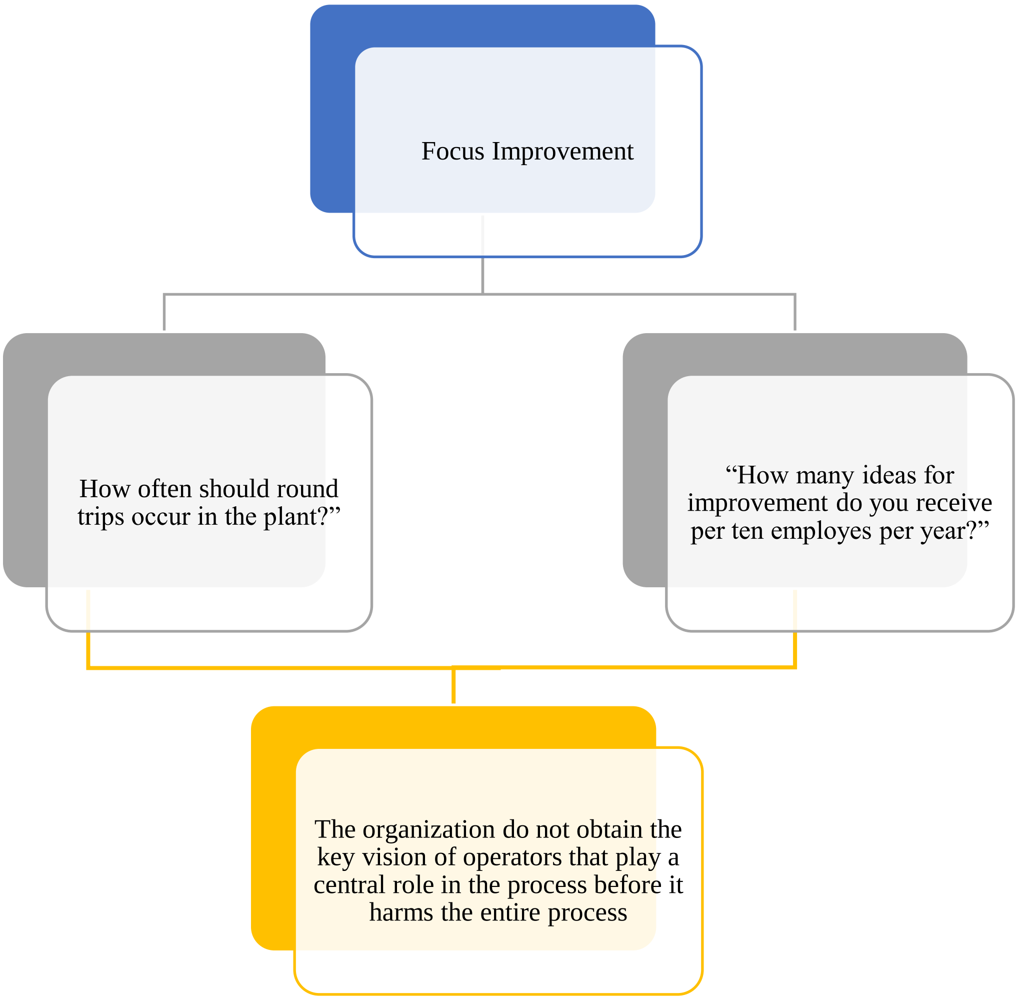

Figure 23 - Affinity Diagram (Focus Improvement pillar)

- The impact that arose from the pillar Quality Maintenance based on the answers of the questions presented before was: A defective product is identified only when it comes out of the production line, which means that the defect is now irreversible or very difficult to correct. If this was happening in critical equipment, it would mean that the entire production from a certain period would be compromised.

The illustration of the generated *Affinity Diagram* is possible to observe in Figure 24.

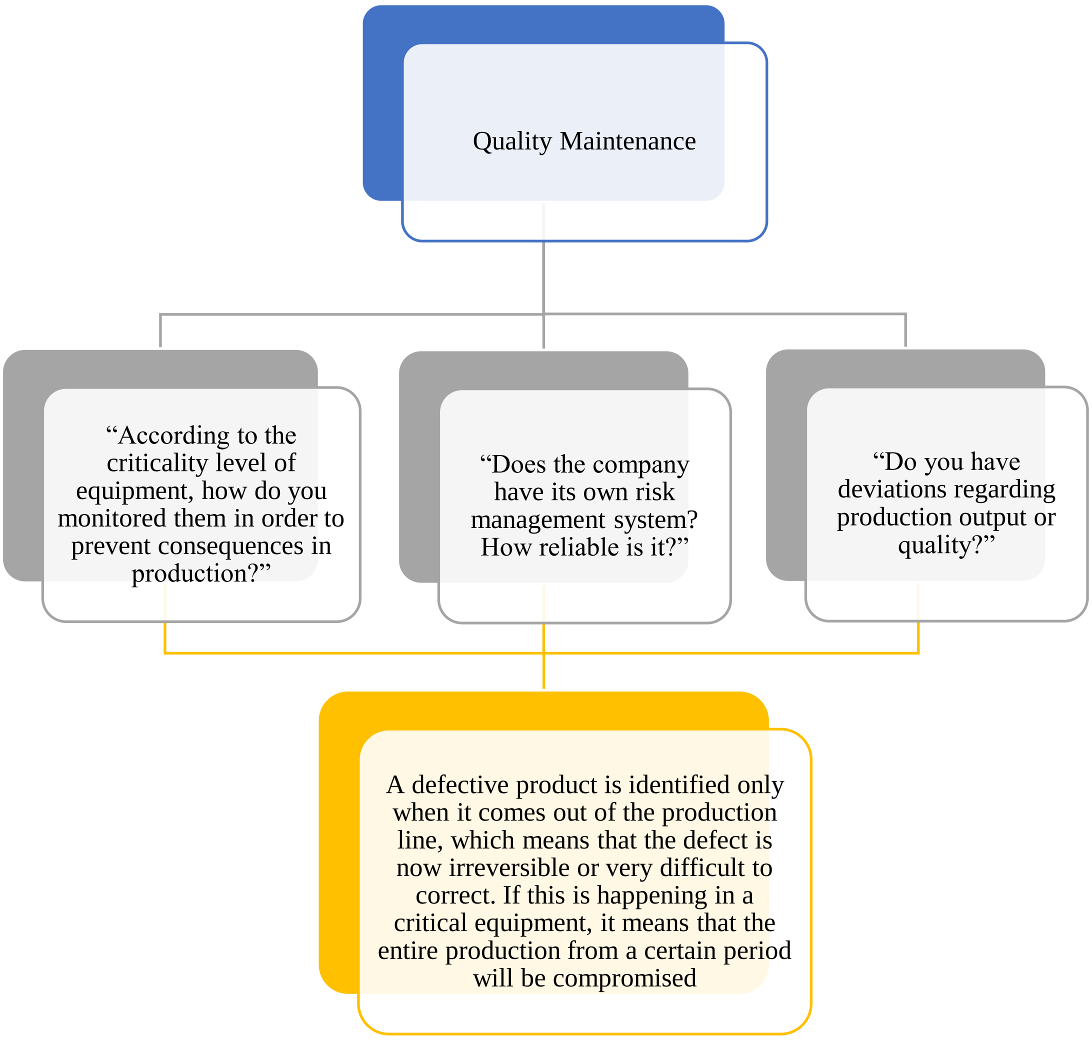

Figure 24 - Affinity Diagram (Quality Maintenance pillar)

- The impact that arose from the pillar Autonomous Maintenance based on the answers to the questions presented before was: The lack of employees working on maintenance and the lack of staff understanding regarding maintenance needs, can result in severe issues that affect the production process. These issues can be translated into the stoppage of the entire production line.

To obtain a graphical representation of this *Affinity Diagram*, Figure 25 is presented.

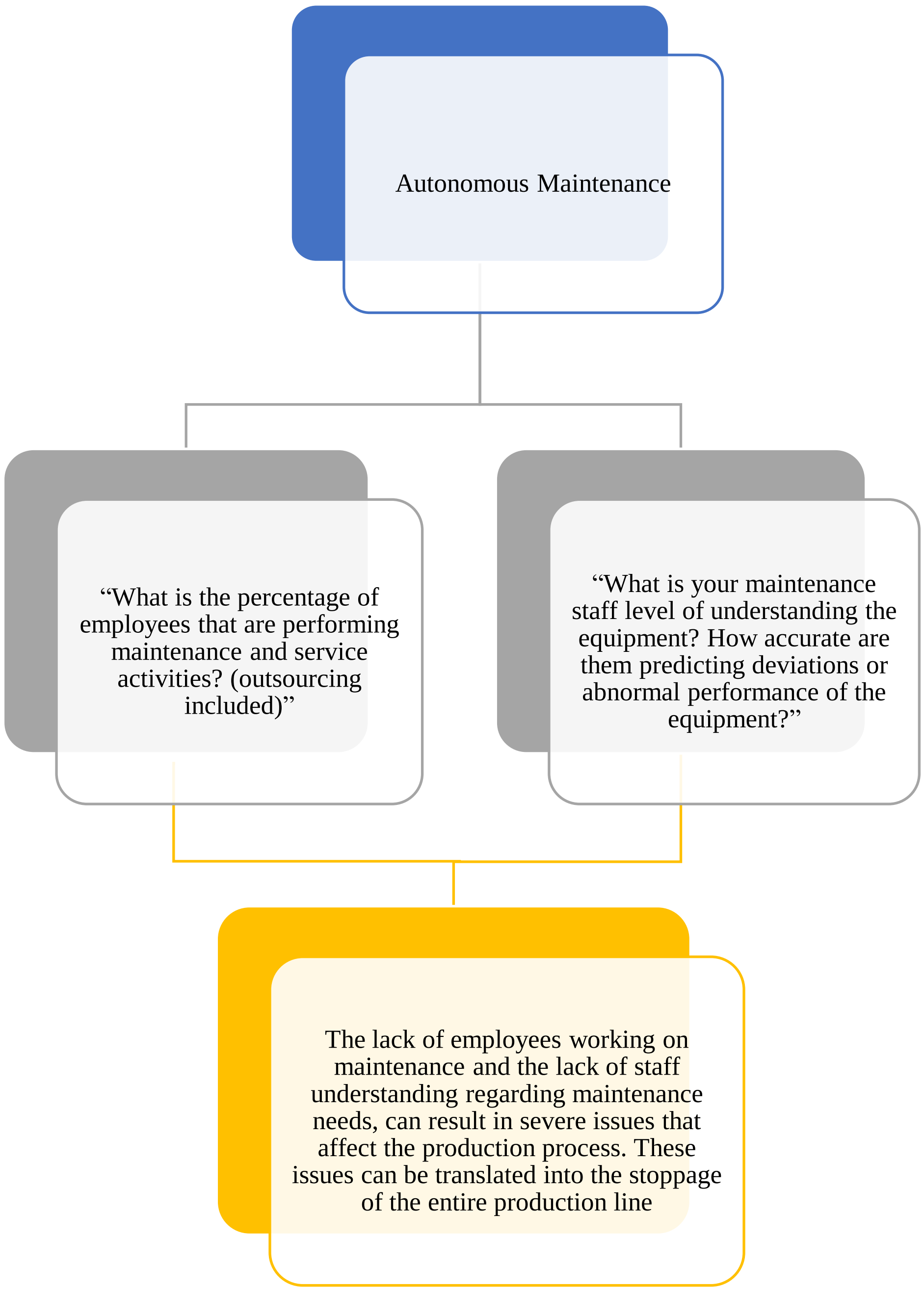

Figure 25 - Affinity Diagram (Autonomous Maintenance pillar)

Step 3. Identify Possible Causal Factors

This step consists in the identification of the causes that could lead to the negative impacts that were found in the previous step, and to do this, it was used the *Cause-and-Effect Diagram*.

So, using the impacts already identified in Step 2, the causes generated are illustrated in the following figures.

- **Focus Improvement pillar**

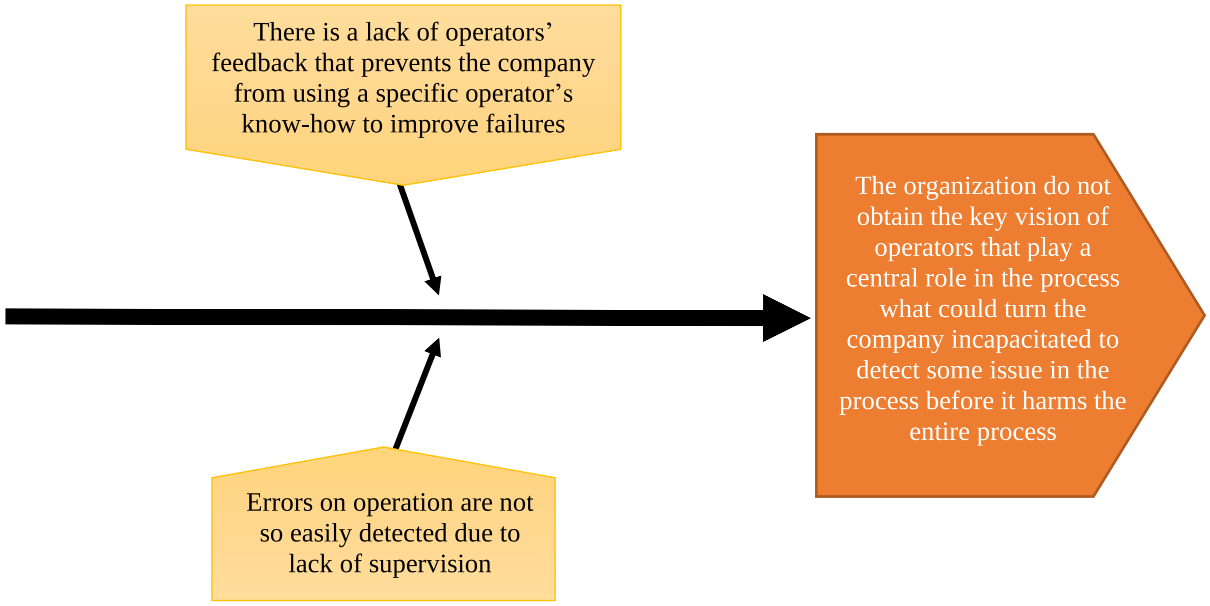

Figure 26 - Cause-and-Effect Diagram (Focus Improvement pillar)

- **Quality Maintenance pillar**

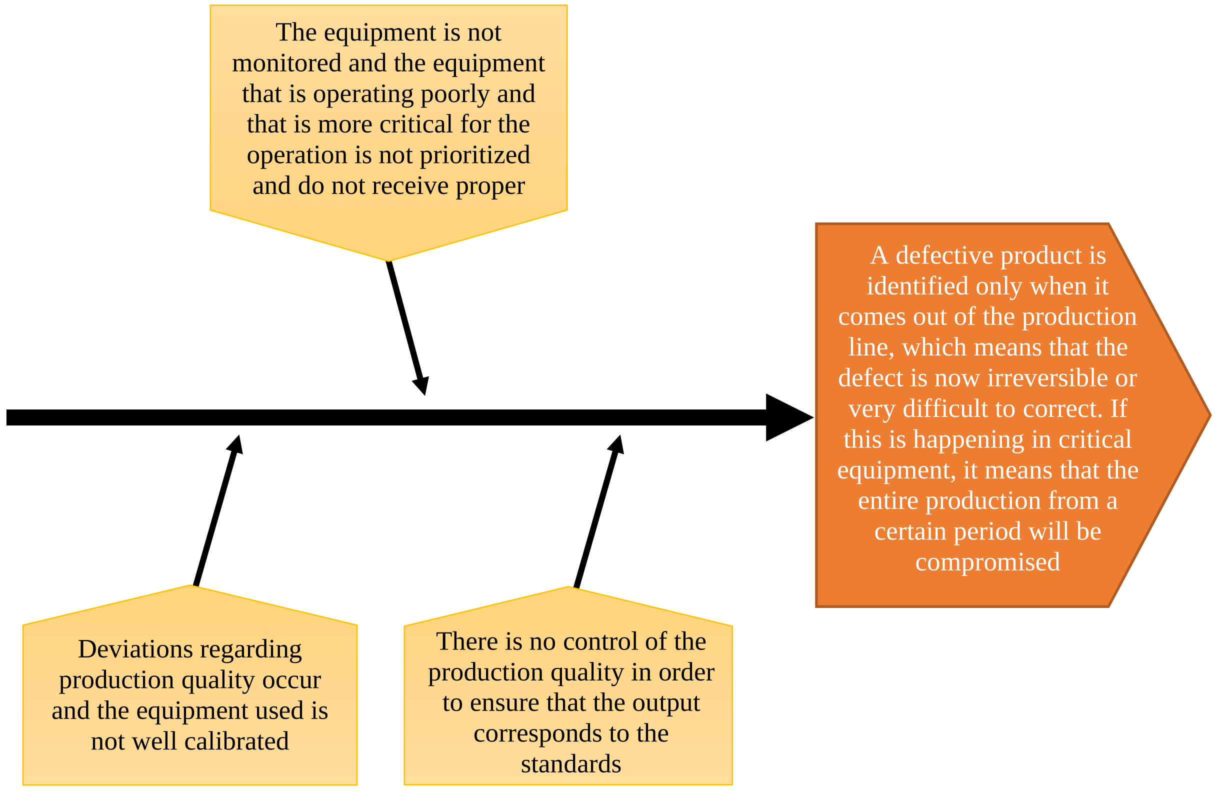

Figure 27 - Cause-and-Effect Diagram (Quality Maintenance pillar)

➢ **Autonomous Maintenance pillar**

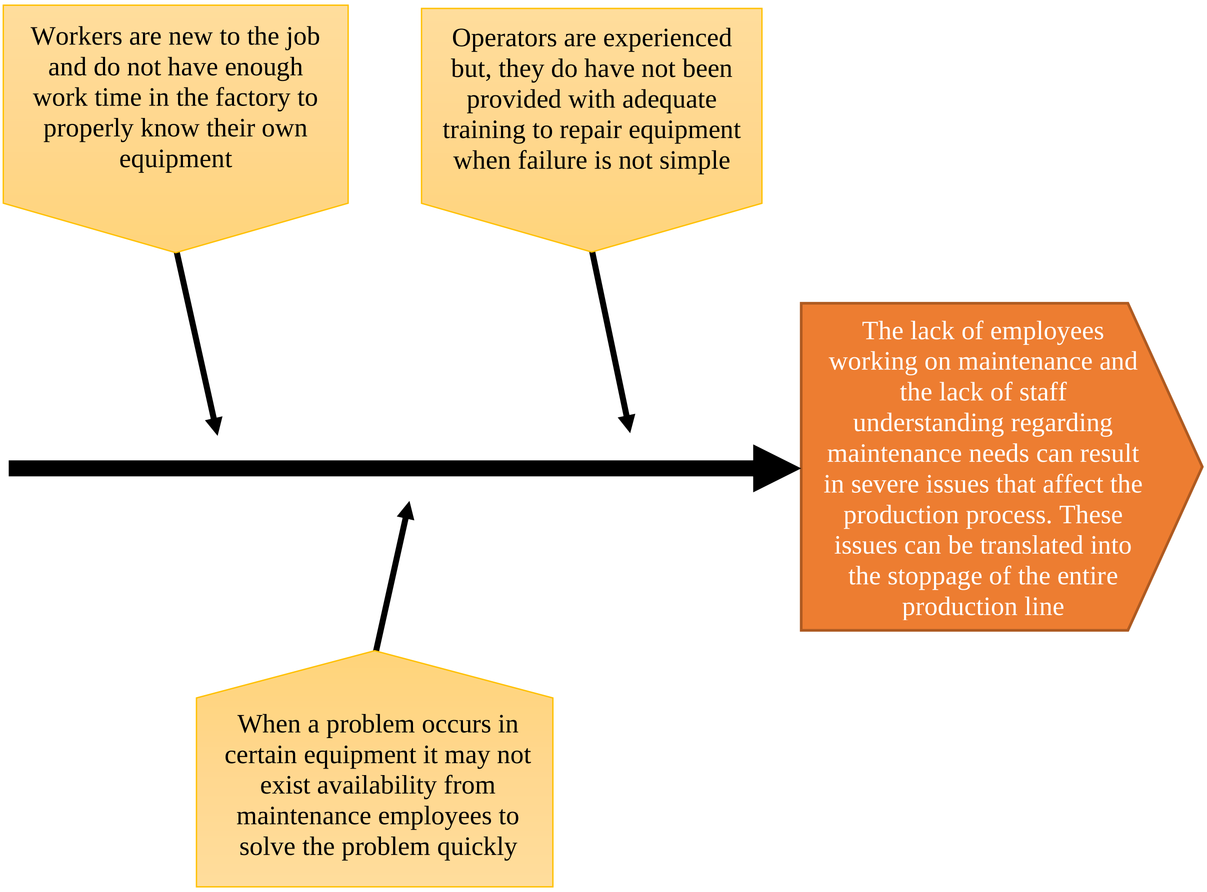

Figure 28 - Cause-and-Effect Diagram (Autonomous Maintenance pillar)

Step 4. Develop Solutions and Recommendations

A – Development of recommendations

Following the impacts and causes previously developed, the recommendations were generated. These recommendations are generated on Microsoft Excel basis according to the customer's answers scores. The average calculation is done by a group of questions and the three groups that have worse scores are selected. Being recommendations linked with all groups of questions, these three recommendations connected to the groups with worse scores are presented to customers to enable them to have the insight of where their plants could improve.

A representation of how recommendations are connected to the impacts, causes, and questions previously mentioned is possible to observe in Figure 29.

Questions	Causes	Evidence/Impact	Recommendations
What is the percentage of employees that are performing maintenance and service activities? (outsourcing included)	When a problem occurs in a certain equipment it may not exist availability from maintenance employees to solve the problem quickly	The lack of employees working on maintenance and the lack of staff understanding regarding maintenance needs, can result in severe issues that affect the production process. These issues can be translated into the stoppage of the entire production line	Provide operators specific training regarding the Autonomous Maintenance of the TPM programme. The goal is to enable employees that operate the machines to perform some maintenance activities and to quickly predict abnormalities in the equipment, transforming them into a multi-tasked work force
What is your maintenance staff level of understanding the equipment? How accurate are them predicting deviations or abnormal performance of the equipment?	Workers are new to the job and do not had enough work time in the factory to properly know their own equipment		
	Operators are experienced but, they do have not been provided with adequate training to repair equipment when failure is not simple		
How often should round trips occur in the plant?	Errors on operation are not so easily detected due to lack of supervision	The organization do not obtain the key vision of operators that play a central role in the process what could turn the company incapacitated to detect some issue in the process before it harms the entire process.	The Kaizen approach should be followed by implementing a system to collect problems identified by operators and their suggestions for improvement. Frequent round trips to the plant will enable to visually understand if processes are flowing accordingly and also will allow to get operators feedback in real-time regarding possible improvements
How many ideas for improvement do you receive per ten employees per year?	There is a lack of operators' feedback that prevents the company from using specific operator's know-how to improve failures		
According to the criticality level of equipment, how do you monetarize them in order to prevent consequences in production?	The equipment is not monitored and the equipment that is operating poorly and that is more critical for the operation is not prioritized and do not receive proper	A defective product is identified only when it comes out of the production line, which means that the defect is now irreversible or very difficult to correct. If this is happening in a critical equipment, it means that the entire production from a certain period will be compromised	Install additional sensors like cameras or laser sensors that can be integrated and connected to the equipment in order to be able to track important process parameters as shape or weight of the production output, in order to identify deviations from the quality standards and avoid defects
Does the company have its own risk management system? How reliable is it?	Deviations regarding production quality occur and the equipment used is not well calibrated		
Do you have deviations regarding production output or quality?	There is no control of the production quality in order to ensure that the output corresponds to the standards		

Figure 29 - Generating Recommendations on the Customer Compass Model (Microsoft Excel basis)

It is possible to observe the Customer Compass model complete, with all the questions, causes, impacts and recommendations evidenced in *Appendix 3*.

B – Check if the recommendations are aligned with the needs of the customer

Given the content of the group of questions and their link to the TPM pillar, the impact found had to be consistent with the ACV-Fingerprint questionnaire. To validate this, it was used the real result from a customer who had already answered the questionnaire and was evaluated by the AVC-Fingerprint, which is possible to be observed in Figure 30.

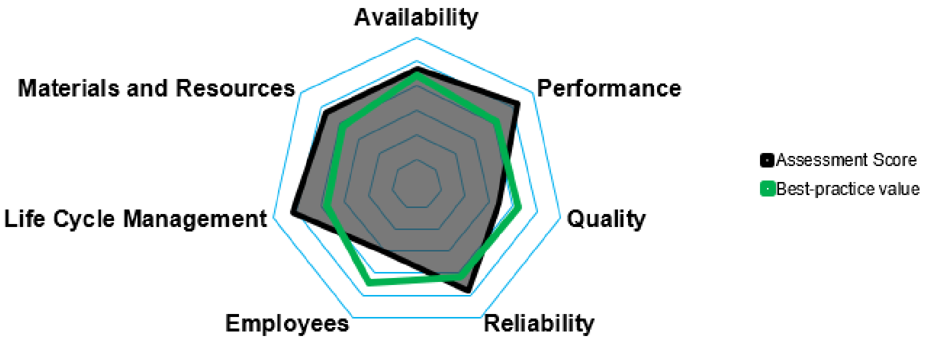

Figure 30 – Customer result of the ACV-Fingerprint Questionnaire

Considering the ACV-Fingerprint evaluation presented in Figure 30, it is possible to understand that the customers' areas that evidenced worse performance were the Employees and Quality parameters. Comparing it to the generated recommendations, it was understood that the results were aligned with the ACV-Fingerprint results, since one of the focus of recommendations were to increase the quality of products by installing additional cameras to the equipment in order to be able to identify deviations from the quality standards and avoid defects, which aims to improve the Quality parameter. Generated recommendations also emphases the importance of the employee to be trained and listened which will improve the issues identified in the Employees parameter.

Step 5: Implement Recommendations

As explained before, this step is to be more detailed in the future and consists in connecting the recommendations developed in this project to potential services that could be provided by the company.

In this example, and based on the conducted study of the main services of the automation sector (*vide Step 5 of section 4.3*), one of the services that could be suggested is the Remote & condition monitoring in order to improve the quality parameter of the customers. With this, the company could not only sell the sensors to install in the customers' equipment, but also could monitor the condition of a component avoiding products' defects.

6. Discussion and Conclusions

In this chapter, the conclusions of this business project are presented, taking into the analysis of the results made in the previous chapter (*vide chapter 5*). Possible answers to the Research Questions (*vide section 1.3*) will be outlined, as well as the main limitations associated with this research, and suggestions for future research will be discussed.

6.1. Propositions Discussion

The creation of the Customer Compass model to generate value-adding recommendations was the chosen theme for this business problem. The choice of this theme had two main reasons, First, the presentation of the model itself, documenting all the requirements, activities, resources involved and the associated benefits. Second, present an example of a model implementation so that it can be applied to new customers and enable the company to start providing services to customers in the future.

Initially, it was sought to identify from the literature review the methodology for the creation of the model that best suited the requirements and context of the company. From the linkage of the three fundamental elements necessary to develop the model, Servitization, TPM, and OEE, it was possible to create recommendations that were adjusted to real customers' needs, what was tested in the application of it on a real case.

It was defined that the main propositions to be discussed are, as follows:

P1. *"Servitization is a way to generate value to the company and its customers (vide sections 1.1.1 and 2.1)".*

P2. *"The ACV-Fingerprint questionnaire identifies the main potential failures of the customers (vide section 1.1.2). The development of recommendations supported by TPM enabled customers to overcome their plant failures (vide sections 1.2 and 2.3.2)".*

P3. *"The generation of recommendations to overcome possible identified customers' plant failures, could allow providing new services supported by these recommendations" (vide sections 1.2 and 2.2)".*

P4. *"Total Productive Maintenance* philosophy *is an appropriate concept to use as a basis on the recommendations' generation (vide section 2.3.1)".*

P5. *"Services on the automation sector are not the core business. However, they can lead towards competitive advantage and increase the OEE metric value (vide sections 1.1.3 and 2.4)".*

Through Servitization, it is possible to offer not only products but services to maintain these products throughout their lifecycle. This allows to build stronger and long-term oriented relationships between customers and manufacturers, which generates value for both parties: in the manufacturer perspective, it enables to increase business volume, since not only the product is being sold, but also a service is being provided; for the customer, it guarantees 100% availability and performance for the products acquire. The company identified exactly this opportunity and is moving on the Servitization direction precisely due to the value it generates (***P1***).

To achieve a Servitization dimension, the ACV-Fingerprint was developed. The objective of the ACV-Fingerprint questionnaire is to identify through an extensive questionnaire the possible failures occurring in customers' plants (*vide section 1.1.2*). The goal of the present business project was to develop a model capable of generating recommendations to answer the previously identified failures and the next step is to link products and services provided by the company to fulfil the recommendations and solve the identified failures. During the development of this business project, the Customer Compass model was tested in one of the real company's customers. After collecting the customer's answers and results, automatic recommendations were generated, highlighting actions to be taken to overcome the main identified failures. By empirical testing this model with a real customer, it was possible to prove that a link existed between the generated recommendations and the ACV-Fingerprint results and when actions provided by recommendations are operationalized, it would be possible to improve these results (***P2***). It was also understood, together with a company representative, that the required actions to overcome the failures identified in the questionnaire could be supported by the company's products or services (*vide section 4.3*) (***P3***).

To make possible the connection between the ACV-Fingerprint and the Customer Compass model, it was necessary to identify a philosophy that aggregates knowledge that, on the one hand, supports the recommendations and on the other hand, includes all the questions thematic. The TPM philosophy proved to be the right choice to use in this context, since its eight pillars englobe the fundamental areas covered by the questionnaire, which enabled to understand the hidden fundamental issues that the questions wanted to access, providing at the same time the necessary knowledge (recommendations) to address them (***P4***).

Since recommendations were developed based on the TPM philosophy, one of the ways how they can add value to customers is by having the potential to increase the OEE metric value of customers plants, which is translated on an increase of efficiency, performance and production quality levels (*vide section 2.4*). In the company perspective, value is generated by offering it the possibility to start providing services, which can allow to increase their businesses volume value and strengthen the relationship with its customers. Examples of manufacturing companies that have been implementing after-sales services in their businesses are Siemens (Siemens website, 2019) and ABB (ABB website, 2019). The Siemens after-sales program has been developed to meet the special needs of makers and marketers of electrical components, equipment, and systems as well as the requirements of machine tool makers and plant engineering companies. They provide a series of service modules: Field- and On-line Service performed directly at customer's site or via online connection (On-site Fault Elimination, Remote Monitoring, Management of Call desks and Helpdesks, On-call Service, Reliability Solutions), Repair Service is services that are performed in Siemens service centres (Repair, Calibration), Logistics Service is services to support and/or optimise customers service processes (Integration of logistics management systems, Management of returns, Spare parts management, Supply of instruments and tools), Service packages comprise service modules that are selected and Review of After-Sales Service Concepts combined according to individual requirements, technical synergy effects, or specific industrial processes (Rolstadaas et al., 2008). ABB service guide provides a full range of lifecycle services from spare parts and equipment repair, training, migration to remote monitoring and technical support. Their services are the following: Performance and System Services (Asset Assessment, Consulting, Optimisation, Performance Services), Support and Maintenance Services (Installation & Commissioning, Maintenance & Field Services, Spare Parts & Repair, Support & Remote Services), Retrofit and Modernization (Environmental, Migration & Retrofits) and Training (Rolstadaas et al., 2008). As these two firms, the company studied also felt the need to start providing services to remain competitive in the market. This was one of the main motivations for the development of this business project and, as discussed in the literature review, as products in the global market become more and more similar, supply chain management and services are becoming key differentiators between companies. High-quality service has become a necessity to retain customers for future sales and also represents a significant revenue and growth potential for capital goods manufacturers (***P5***). By having collected the results of the ACV-Fingerprint in order to find out which failures are more common in their customers' plants and by having understanding the reasons for those failures to happen and developing recommendations to overcome them with the Customer Compass model, the company is able to start providing services to their customers in a recent future. After studying the main services of the automation sector, a link with recommendations is expected to enable the company to start offering services to their customers.

With the discussion of the propositions and after the development of all the procedures in this business project, it is possible to affirm that, if the work done is pursued, the company will be able to become a service provider in the recent future.

6.2. Revisiting the Research Questions

In this section, the answers to the Research Questions initially proposed are presented, as well as the inherent curiosities of the research that followed to meet the research objective, the development of recommendations to customers' plants.

1) **How to develop recommendations that add value to both the company and its customers based on the ACV-Fingerprint result?**

To answer the first research question, it required a lot of research to understand which literature could help to understand how Servitization could be performed in order to add value to the company and its customers. According to Neely (2008), Servitization is essential nowadays because if manufacturing companies aspire to remain competitive in the market, they appear rarely to stay as pure manufacturing firms. In the literature, as previously referred, Servitization is also mentioned as the Product-Service (P-S) transition, representing a transition between pure product to pure service offerings. This was exactly what the company wanted to do by creating the ACV-Fingerprint to access the needs of its customers' plants, but the company needed to have some specific recommendations to provide to their customers according to the possible ACV-Fingerprints results that would be the way to create value to both of the actors. To do this, the TPM philosophy, that is a manufacturing program designed primarily to maximize equipment effectiveness throughout its entire life through the participation and motivation of the entire workforce, was used as the base of the study in order to prove the creation of value and be able to understand all the possible results of the ACV-Fingerprint. Through the connection of the eight TPM pillars and the ACV-Fingerprint questions, it was possible to obtain the knowledge necessary to identify the potential value of helping to improve the failures of the customers' plants and, in the future, can help the company to create value through offering more customization, more quality and reduce risk by making customers' costs more predictable.

2) **What methodology could be used to help structure problem resolution?**

The Root Cause Analysis methodology is a step-by-step methodology that leads to discover the prime cause of a failure and, in this context, it could provide a structured way to obtain the causes and impacts for the different ACV-Fingerprint results. This methodology was the chosen one to structure the problem resolution since it is a tool that provides a guide of the necessary steps to solve a business problem and helps to structure a way to arrive at the root cause of it. Consists in a six-step process that were previously exposed in Chapter 4 - Methodology.

3) **How to understand the impacts of the questions provided by the ACV-Fingerprint?**

One of the steps of the RCA methodology is the identification of the possible causal factors. As mentioned before, several tools can help to identify causal factors following the RCA methodology. The Cause-and-Effect Diagram identifies the most likely causes to happen in order to help the improvement team that will focus on the most highlighted cause in order to prevent it from happening again. This was the reason for being the tool chosen.

With the connection of the ACV-Fingerprint with the eight TPM pillars, it was possible to obtain the impact of each group of questions. So, having the impact, it was possible to obtain the causes of that impact using the fishbone diagram.

4) **Which recommendations could be developed to overcome the impacts obtained?**

This question relies on the objective of this business project. All the procedures were done having in mind this goal, the development of recommendations that could improve the customers' plants, improve their failures and also be able to add value to the company in the future by matching these recommendations to potential services. The recommendations were developed using the TPM philosophy and through the identification of the causes and impacts of the possible answers in the questionnaire.

6.3. Project Contributions

In general, the development of this business project contributes for different areas.

In the research filed, the project offers a conceptual framework developed based on formulated propositions supported by the literature review. It focuses on the development of a model capable of generating customer-oriented recommendations that can generate relevant inputs for the development of new products and services by the company, improving customers' plants performance and the company businesses volume.

By aggregating the customers results on a questionnaire where it is possible to assess customers main plant needs, and by studying the Total Productive Maintenance philosophy focusing on its 8 pillars, solutions were developed in order to add value for both parties. The developed recommendations can be linked to potential services and can enable future researchers to start developing their own services specific needs.

Finally, by conducting this business project, it was possible to contribute for the practitioner through the testing of the developed model on a real customer of the company, since the achieved results allowed to understand which beneficial factor could arise for both the customer and the company. It was also suggested future actions to continue this work that will be detailed in the following section.

6.4. Suggestions for Future Work

As previously mentioned, the present work is focused on the development and implementation of the Customer Compass model. Thus, every procedure that has been presented takes into account the goal of this business project. The idea is that in the future the company could start to provide services to its customers by continuing the work and study that was conducted. Thus, there is a set of suggestions for future research to pursue the work done:

- Test on new clients the remaining recommendations;
- Verify the traceability of issues to avoid possible incongruities;
- Store the tested customer results to ensure the effectiveness of recommendations for each problem detected and each customer business area;
- Introduce new questions so that recommendations can be better tailored to a particular customer, not automatically, but personalized;
- Connect the recommendations developed to potential services to enable the company to start to provide not only products but also services to its customers.

6.5. Study Limitations

The main limitation of this work is related to the fact that only one of the company's customers was tested with the developed model. According to Yin (2009), the use of multiple case studies allows a closer approximation of the global market reality. Thus, despite the conclusions and findings in the literature, it is necessary to strengthen the study of the recommendations by testing them with more customers in order to properly link them to potential services.

The other limitation for the business project was that recommendations that were developed had to be generic and standardized because they were intended to serve many companies of different business areas and different sizes. Since the company's customers deeply vary in terms of employees' numbers and terms of implemented technology, it was not possible to develop more tailored and customized recommendations to really suit all customers' realities.

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Appendices

Appendix 1. ACV-Fingerprint Questionnaire (Microsoft Excel basis)

The appendix 1 presents the structure of the ACV-Fingerprint questionnaire. It contains 4 workbooks and 48 questions (*vide section 1.1.2*)

	Questionnaire 1: Organization	Please rate 1-6	(Your notes)	Choices: Choice 1 - excellence	Choice 2 - challenge for lead	Choice 3 - potential	Choice 4 - amber light	Choice 5 - need for action	Choice 6 - fire fighting
1.1	**Organization**			Answer for 1	Answer for 2	Answer for 3	Answer for 4	Answer for 5	Answer for 6
1.1.1	What is the percentage of employees that are performing maintenance and service activities? (outsourcing included)			batch:>10% conti: >20%	batch:10% conti: 18%	batch:8% conti: 15%	batch:6% conti: 12%	batch:4% conti: 10%	batch:2% conti: 8%
1.1.2	On average, in percentage, how many times errors occur due to bad planning?			0-5%	5-10%	10-20%	20-30%	30-40%	>40%
1.1.3	How close do production and planning work together? Are there any fixed procedures or periodical meetings?			daily shop floor meeting, fixed procedure	shop floor meeting twice a week	weekly shop floor meeting	in contact, no fixed frequency, but standardized procedure	in contact, but no fixed frequency	no contact
1.1.4	How close do management (HQ) and production planning work together?			weekly shop floor meeting	shop floor meeting twice a month	monthly shop floor meeting	in contact, no fixed frequency, but standardized procedure	in contact, but no fixed frequency	no contact
1.1.5	How close do the logistics and production work together?			daily shop floor meeting, fixed procedure.	shop floor meeting twice a week	weekly shop floor meeting	no fixed frequency, but standardized procedure	in contact, but no fixed frequency	no contact
1.1.6	How many ideas for improvement do you receive per ten employees per year?			>7	6-7	4-5	3-4	1-3	0-1
1.1.7	What should be the ideal training time for maintenance people?			>70h	49-70h	35-49h	16-35h	8-16h	0-8h
1.1.8	Are the conducted trainings more practical (hands-on) or theoretical (presentations)? Is there any test with a dedicated certificate after the training?			theoretical with practical test	theoretical with hands-on practice	theoretical with short hands-on practice	theoretical with test	theoretical without test	no training
1.1.9	What is your maintenance staff level of understanding the equipment? How accurate are them predicting deviations or abnormal performance of the equipment?			very good understanding of equipment. Prediction is accurate and early	good understanding of equipment. Prediction is often accurate	some understanding of equipment. Prediction is sometimes accurate	only the maintenance manager may have understanding. Prediction is seldom accurate	only the maintenance manager have poor understanding. Prediction is not accurate	no understanding
1.1.10	Do you have continuous actions related to energy efficiency improvement?			yes, formal and transparent process with milestones is in place	yes, formal process without milestones is in place	yes, some kind of process is in place	no, time-to-time actions in between normal work	no, sometimes single actions if there is a demand	no
1.1.11	Do you have continuous actions related to HSE - health, safety, environment - improvement?			yes, formal and transparent process with milestones is in place	yes, formal process without milestones is in place	yes, some kind of process is in place	no, time-to-time actions in between normal work	no, sometimes single actions if there is a demand	no

Figure 32 – ACV-Fingerprint Questionnaire (Organization Workbook)

	Questionnaire 2: Life-cycle and Production	Please rate 1-6	(Your notes)	Choices: Choice 1 - excellence	Choice 2 - challenge for lead	Choice 3 - potential	Choice 4 - amber light	Choice 5 - Need for action	Choice 6 - fire fighting
2.1	**Life-cycle and Production**			Answer for 1	Answer for 2	Answer for 3	Answer for 4	Answer for 5	Answer for 6
2.1.1	When was the last modernization of the automation equipment?			<2 years	2-5 years	5-10 years	10-15 years	15-20 years	>20 years
2.1.2	Do you have a life-cycle management system that supports the assessment of management and maintenance planning?			yes, interdisciplinary and plant-wide integrated. System, interacts with components automatically and considers conditions and required actions	yes, interdisciplinary and plant-wide integrated. System is mainly automatic and partly manual maintained	yes, interdisciplinary and plant-wide integrated. System is manually maintained	yes, a computer-based system is in place and manually maintained	yes, a hand-written daybook-based system is in place	no system or documentation available
2.1.3	How do you assess the life-cycle status of your equipment?			life-cycle management system gives report automatically	life-cycle management gives report upon request	maintenance responsible knows status of life-cycle and required actions	maintenance responsible knows status of life-cycle	maintenance responsible partially knows the status of life-cycle	information about life-cycle status can not be assessed
2.1.4	How often do you verify the working conditions of your equipment?			according to the manufacturer's recommendations or industry advice	in regular intervals of time defined by the company	according to the intensity of use	before evey audit	when some operator complains	never, run until failure
2.1.5	Do you replace the existing equipment by the same technology or do you check for a state-of-the-art solution?			yes, state-of-the-art will always be taken	yes, state-of-the-art will be checked	if necessary, depending on requirements in future	only if immediate demand	only if cost is lower than existing solution	no, replacement with exactly same product
2.1.6	According to the criticality level of equipment, how do you monetarize them in order to prevent consequences in production?			every equipment has its specific critical level and is monitorized according to its criticality	every equipment has its specific critical level, but is not monitorized according to its criticality	every equipment is associated with the same general critical level	the equipment critical level is only identified when it fails	no knowledge regarding equipment criticality, and few monitorization	any equipment is monitorized
2.1.7	Is the automation equipment implemented in a redundant way for critical production processes?			critical equipments are redundant and modular for simple replacement	some critical equipments are redundant and modular for replacement	some critical equipments are redundant	few critical equipments are redundant	no redundancy, but interest	no redundancy planned
2.1.8	What percentage of time do you use to deal with unplanned actions?			0-5%	5-10%	10-20%	20-30%	30-40%	>40%
2.1.9	Do you have deviations regarding production output or quality?			no deviations	some small uncritical deviations	deviations only during start-up and stop	deviations in output, but not in quality	output is lower, quality is difficult to handle	output is lower, quality is very difficult to handle
2.1.10	How do you monetarize the performance of the system?			online, remote, and condition monitoring	manual condition monitoring	inspection every month	inspection every calendar quarter	inspection every year	no monitoring or inspection
2.1.11	How often do you check the production plant performance?			real-time	daily	twice a week	once a week	once a month	once a calendar quarter
2.1.12	How often should round trips occur in the plant?			once an hour	once a work-shift	once a day	once a week	once a month	less than once a month
2.1.13	In percentage, how many times do you run a root-cause-failure analysis when unplanned shutdowns occur?			80-100%	60-80%	40-60%	20-40%	1-20%	0%

Figure 31 – ACV-Fingerprint Questionnaire (Life-cycle and Production Workbook)

Questionnaire 3: Plant - specs and reliability		Please rate 1-6	(Your notes)	Choices					
				Choice 1 - excellence	Choice 2 - challenge for lead	Choice 3 - potential	Choice 4 - amber light	Choice 5 - Need for action	Choice 6 - fire fighting
3.1	Specs and Reliability			Answer for 1	Answer for 2	Answer for 3	Answer for 4	Answer for 5	Answer for 6
3.1.1	How high is your availability in %?			conti: >95% batch: >85%	conti: <93-95% batch: 80-85%	conti: <90-93% batch: <75-80%	conti: 85-90% batch: <70-75%	conti: 75-85% batch: 60-70%	conti: <75% batch: <60%
3.1.2	How high is your performance in %?			conti: >95% batch: >85%	conti: <93-95% batch: 80-85%	conti: <90-93% batch: <75-80%	conti: 85-90% batch: <70-75%	conti: 75-85% batch: 60-70%	conti: <75% batch: <60%
3.1.3	How high is your quality rate in %?			conti: >95% batch: >85%	conti: <93-95% batch: 80-85%	conti: <90-93% batch: <75-80%	conti: 85-90% batch: <70-75%	conti: 75-85% batch: 60-70%	conti: <75% batch: <60%
3.1.4	In percentage, how much do the installed components fulfill the required flexibility regarding changes in the production setup?			>95%	90-95%	80-90%	50-80%	10-50%	0-10%
3.1.5	Do you track your productivity? Is the production process reported and documented in detail?			yes, full process documentation of every product	yes, process documentation of production-batch	yes, tracking - unclear or vague documentation	yes we track but not save in database	no, not today, but maybe in future	no
3.1.6	Does the current installed base fulfill requirements concerning low maintenance?			all components fulfill the requirements	the most part of components fulfill the requirements	partly	fulfill, but not satisfactory	not satisfactory	no
3.1.7	Do you know which air quality class is required in your process? Do you measure it to ensure the required quality?			yes I know the quality class and measure it with sensors. If the tolerance is exceeded an alarm occur.	yes I know the air class. It is manually monitored once per week	yes I know the air class. It is time to time manually monitored	I only replace the filters if necessary.	air quality class was defined at the design phase. Since them, no maintenance has been done	I don't know the class
3.1.8	How often does the air preparation equipment fail?			no fail	very rare failure	rare failure	infrequent failure	often	very often
3.1.9	How easily can the machine be optimized or retrofitted?			modular build, complete scalable	optimization is easy to realize	optimization is part of product change	optimization is possible	optimization need special measures who have to be implemented	no optimization
3.1.10	Does the company have its own risk management system? How reliable is it?			yes, it is well accepted, fully autonomous, reliable and tested	yes, it is implemented, fully autonomous, high rate of reliability.	yes, it is implemented, but in beta or alpha phase	no, but implementation is planned	not yet implemented, but interested in implementation	not implemented
3.1.11	Do you stop the system immediately when it deviates from the range of tolerance or is there any control loop?			yes, complete shutdown	yes, shutdown if critical value strikes.	research before shutdown	research the critical parts before shutdown	no shutdown	no system available
3.1.12	How often does any false alarm happen in the system?			< once a year	half a year	monthly	weekly	daily	every hour

Figure 34 - ACV-Fingerprint Questionnaire (Plant-Specs and Reliability Workbook)

Questionnaire 4: Maintenance		Please rate 1-6	(Your notes)	Choices					
				Choice 1 - excellence	Choice 2 - challenge for lead	Choice 3 - potential	Choice 4 - amber light	Choice 5 - Need for action	Choice 6 - fire fighting
4.1	Maintenance and Spare-Parts			Answer for 1	Answer for 2	Answer for 3	Answer for 4	Answer for 5	Answer for 6
4.1.1	Do you have a management system for maintenance? How well is it integrated?			maintenance system implemented, high reliability, maintenance process implemented	maintenance system implemented, high reliability but no process implemented	maintenance system implemented, middle reliability	no maintenance system implemented, maintenance performs well but there is a high potential for	no system integrated, maintenance actions just on request	no system or no reliable system
4.1.2	Do you have an external service provider, who assists you in maintenance of spare-parts management?			yes, I have a service provider					no, I do not have any service provider
4.1.3	How many suppliers of spare parts are involved?			1-3	3-5	5-7	7-10	10-15	>15
4.1.4	Which maintenance strategy is used in your plant?			predictive with real-time condition monitoring	predictive, with manual monitoring	preventive, with individual intervals. Time period depends on the runtime	preventive, with individual intervals. Time period is fix	reactive, with intuitive replacement	reactive, when breakdown occurs.
4.1.5	Do you know which are the next components that will require maintenance? How do you assess this information?			predictive with real-time condition monitored maintenance	preventively monitored maintenance signaling	A data based worksheet provides the end of the given lifetime	A paper-based worksheet gives the end of the given lifetime	The component that fails is to be maintained the next	No, I do not know
4.1.6	How is your time of response, on average, in performing maintenance activities that require to stop the system?			very fast	fast	acceptable	improvable	long time	extremely long time
4.1.7	How dangerous is the physical access to the equipment that need to be maintained?			simple access, no additional scaffold needed, not dangerous	reasonably simple access, no additional scaffold needed, not dangerous	reasonably simple access, additional mobile working platform required, not dangerous	reasonably simple access, additional mobile working platform required, dangerous	difficult access, additional scaffold needed, extreme dangerous	extremely difficult access, additional scaffold needed, extreme dangerous
4.1.8	Do you test the system before bringing it back into operation?			test of equipment before use	test of part of the equipment before use	time to time test	test just for critical parts	no test due to time limitations	no test
4.1.9	Do you store spare parts in the plant or off-site? How big is your spare parts stock?			own full automatic spare-parts warehouse. (in source or consignations warehouse)	large spare-parts stockpile	small spare-parts stockpile	off-campus warehouse with short delivery	spares have to purchase individually	off-campus, purchase necessary
4.1.10	How reliable are deliveries of spare parts? Is there any logistics process that guarantees deliveries?			high reliability, Just-in-time and Kanban process implemented	high reliability, but no process implemented	middle reliability	spare-Parts delivery works but has potential for	spare-parts purchase if necessary	not reliable
4.1.11	What is the turnover ratio, regarding spare parts?			very high	high	moderate	low	Very low	I don't know
4.1.12	How long does it take (on average) from ordering a spare part until it is installed?			<3h	3-6h	6-12h	12-24h	24-48h	>48h

Figure 33 - ACV-Fingerprint Questionnaire (Maintenance Workbook)

Appendix 2. Affinity Diagrams (Microsoft Excel basis)

This appendix consists on the creation of *Affinity Diagrams* (*vide Step 2 of section 4.3*) with the objective of exploring the connection between the ACV-Fingerprint questions and the Total Productive Maintenance philosophy, in order to discover which impacts could emerge from the customers' answers. This procedure was conducted on Microsoft Excel and was performed by grouping the eight TPM pillars, Autonomous Maintenance (Figure 35), Quality Maintenance (Figure 36), Office Improvement (Figure 37), Focus Improvement (Figure 38), Training and Development (Figure 39), Planned Maintenance (Figure 40), Development Management (Figure 41) and Safety, Health and Environment (Figure 42), with all forty-eight questions included on the ACV-Fingerprint, which led to find eight possible impacts.

a) Autonomous Maintenance (2 questions, 1 impact)

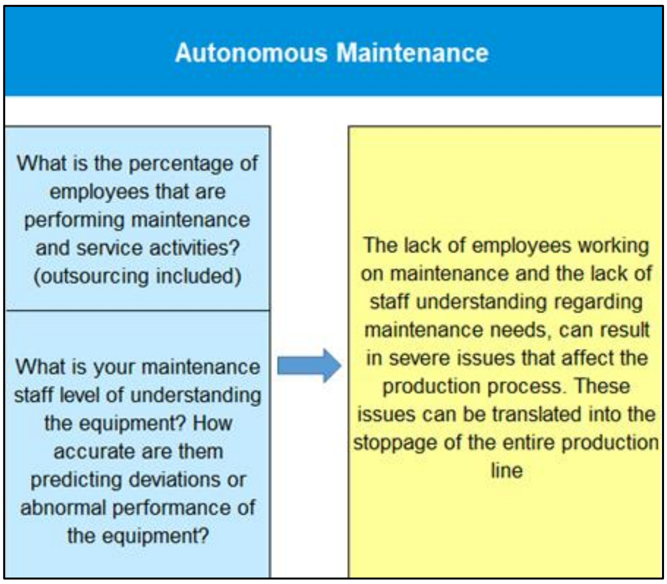

Figure 35 - Affinity Diagram of the Autonomous Maintenance pillar

b) Quality Maintenance (5 questions, 2 impacts)

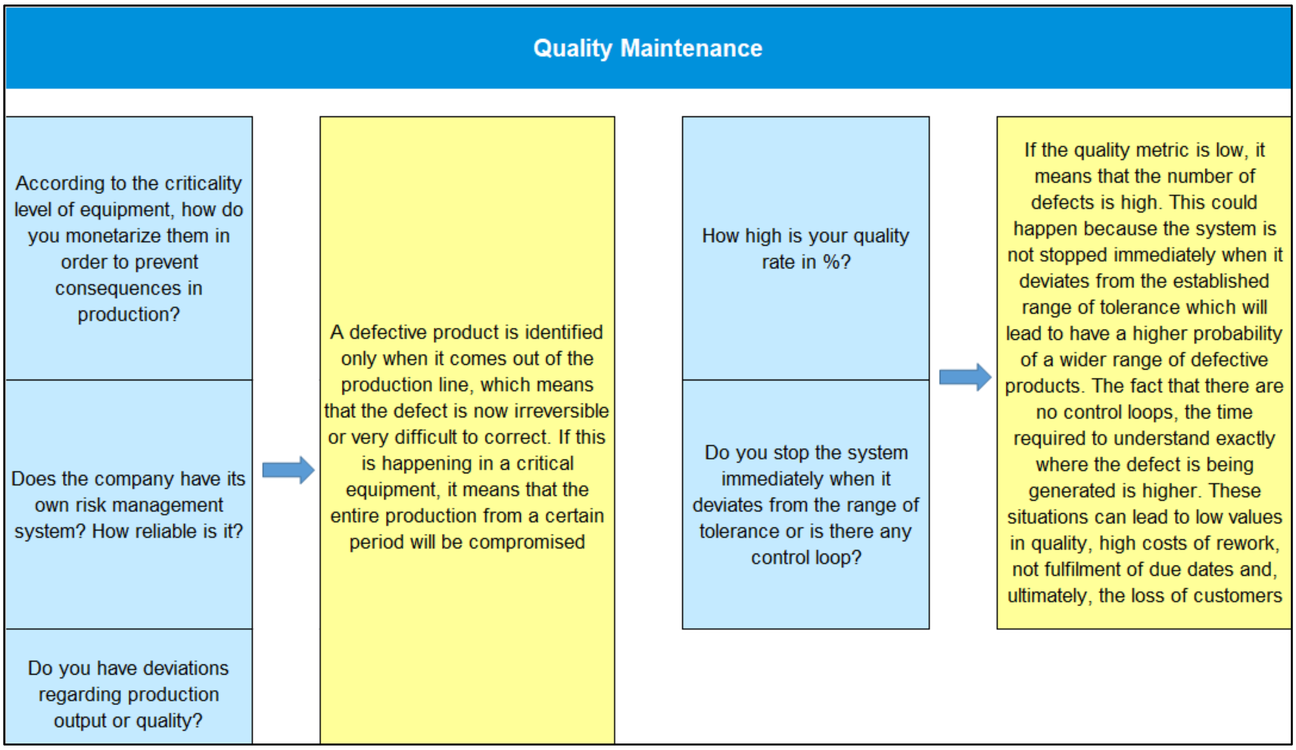

Figure 36 - Affinity Diagrams of the Quality Maintenance pillar

c) Office Improvement (6 questions, 2 impacts)

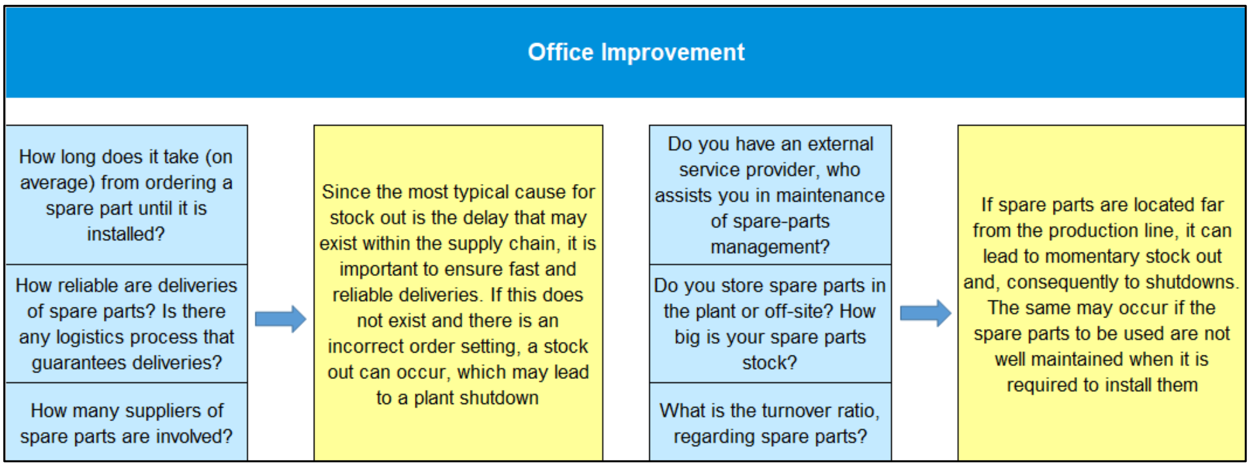

Figure 37 - Affinity Diagrams of the Office Improvement pillar

d) Focused Improvement (10 questions, 3 impacts)

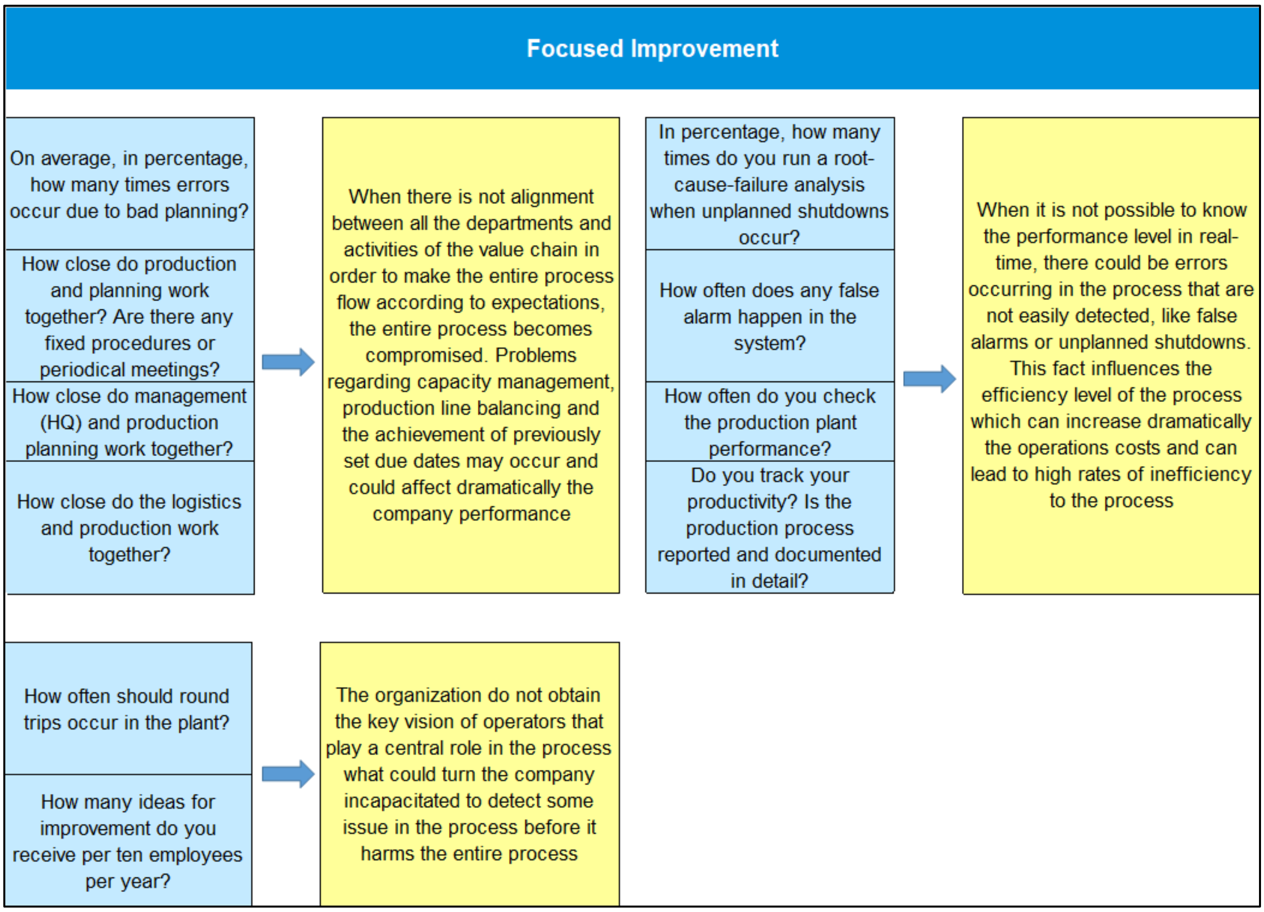

Figure 38 - Affinity Diagrams of the Focus Improvement pillar

e) Training and Development (3 questions, 1 impact)

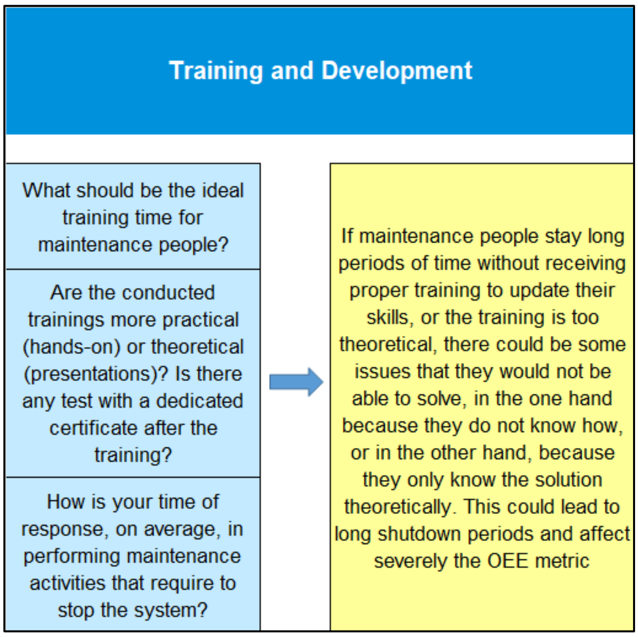

Figure 39 - Affinity Diagram of the Training and Development pillar

f) Planned Maintenance (10 questions, 4 impacts)

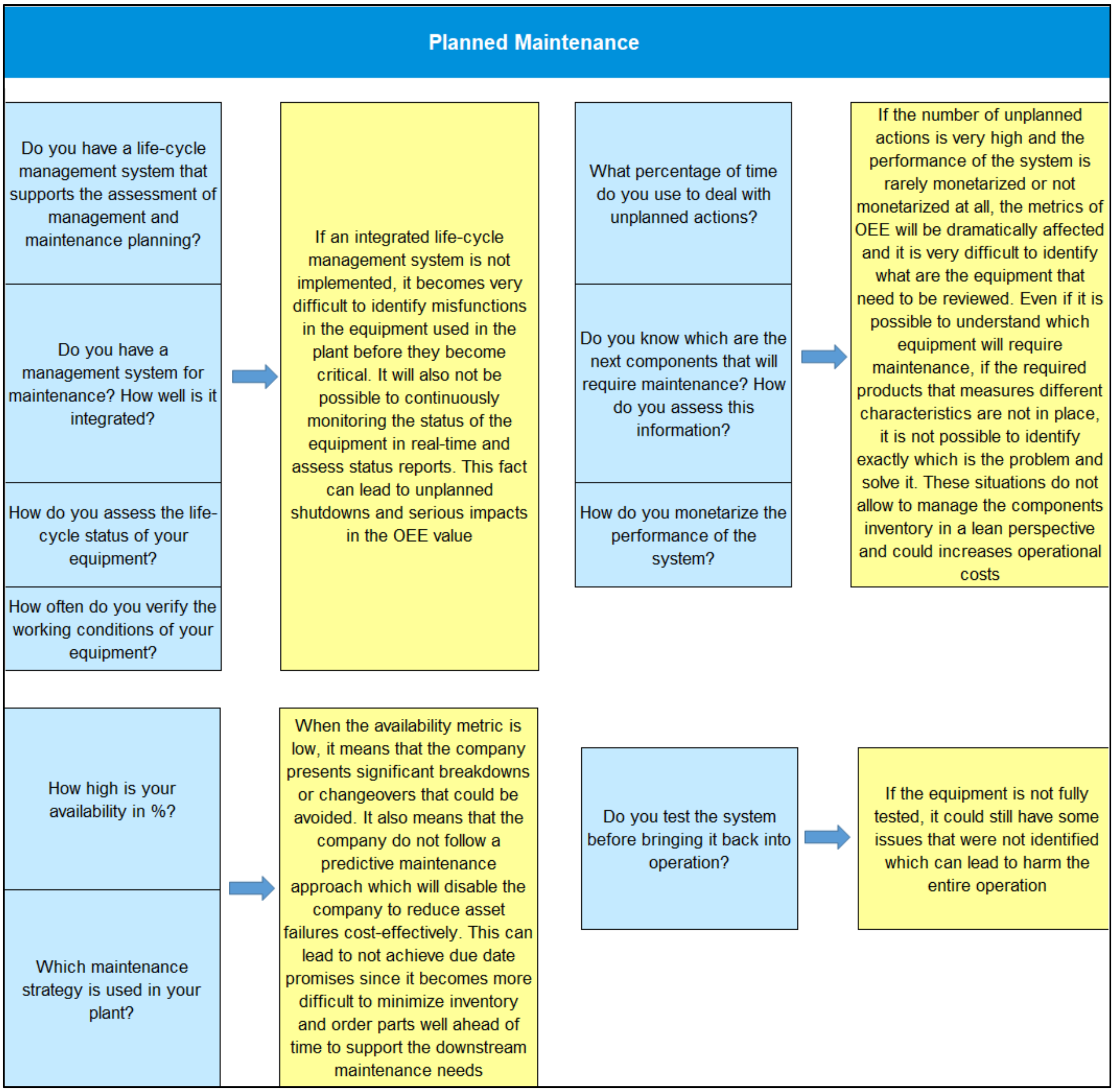

Figure 40 - Affinity Diagrams of the Planned Maintenance pillar

g) Development Management (7 questions, 3 impacts)

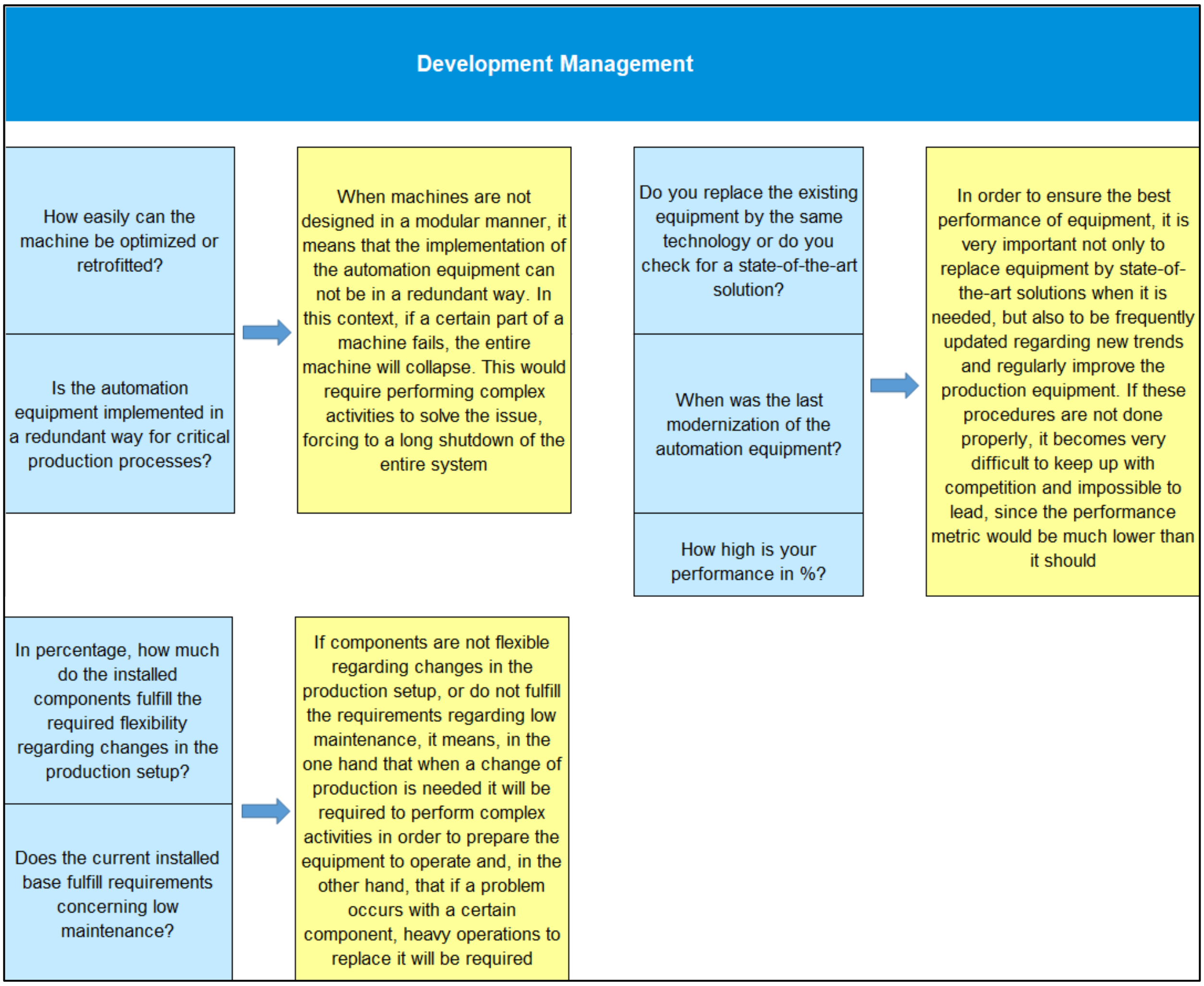

Figure 41 - Affinity Diagrams of the Development Management pillar

h) Safety, Health and Environment (5 questions, 2 impacts)

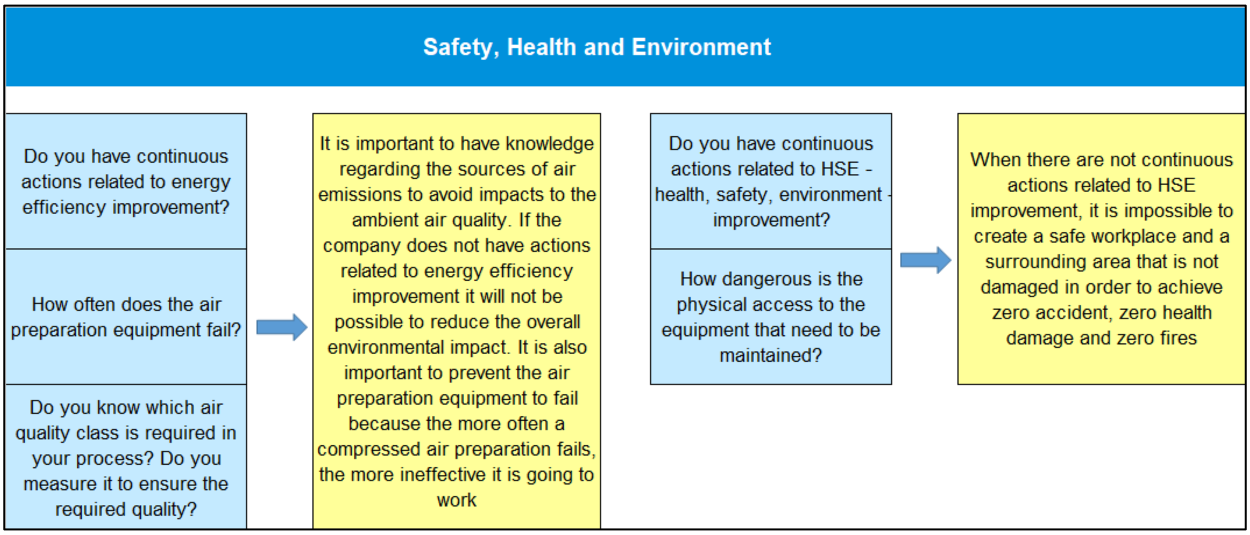

Figure 42 - Affinity Diagrams of the Safety, Health and Environment pillar

Appendix 3. Customer Compass Model (Microsoft Excel basis)

This appendix is an illustration of how the Customer Compass model (*vide chapter 5*) was developed on Microsoft Excel. It is possible to observe how recommendations were generated by grouping questions in order to find the answers' impacts and causes for those impacts to happen. As on the previous appendix was presented, the questions were grouped using the TPM philosophy. So, after these groups were performed, recommendations were generated. In figures bellow, it is possible to observe that are associated with the Safety, Health and Environment pillar two recommendations (Figure 43), one recommendation is related to the Autonomous Maintenance pillar (Figure 44), two recommendations are connected to the Quality Maintenance pillar (Figure 45), three recommendations are related to the Focus Improvement pillar (Figure 46), for recommendations are associated with the Planned Maintenance pillar (Figure 47), one recommendation is connected to the Training and Development pillar (Figure 48), two recommendations are associated with the Office Improvement pillar (Figure 49) and also three recommendations are related to the Development Management pillar (Figure 50).

a) Safety Health and Environment (2 impacts, 2 recommendations)

TPM Pillars	Questions	Causes	Evidence/Impact	Recommendations
Safety, Health and Environment	Do you have continuous actions related to energy efficiency improvement?	Having continuous actions for energy efficiency improvement enables a business to conserve and lower energy demand by reducing ongoing energy usage	It is important to have knowledge regarding the sources of air emissions to avoid impacts to the ambient air quality. If the company does not have actions related to energy efficiency improvement it will not be possible to reduce the overall environmental impact. It is also important to prevent the air preparation equipment to fail because the more often a compressed air preparation fails, the more ineffective it is going to work.	Install valves or drives to support air preparation and reduce possible failures. In some air preparation, a higher percentage of oil wastes the valve or drive mechanism. Therefore, it is important to use the right filter systems that should be implemented as well
	How often does the air preparation equipment fail?	When the air preparation fails regularly, it can result in an incorrect dimensioning of the filters and create impact on the quality of the air. The fact that quality of the air is not correctly measured and known, pollute emissions can harm the performance and lead to a need for optimizations		
	Do you know which air quality class is required in your process? Do you measure it to ensure the required quality?			
	Do you have continuous actions related to HSE - health, safety, environment - improvement?	There is not any continuous action related to HSE - health, safety, environment - implemented in the company	When there are not continuous actions related to HSE improvement, it is impossible to create a safe workplace and a surrounding area that is not damaged in order to achieve zero accident, zero health damage and zero fires	Train employees about what to do in case of emergency and conduct an emergency exit plan. Implement a diagnostic system which will enable to ensure safe operation of the machine or a safety device to laminate or reduce risk operations. Use the 5S technique in order to promote an efficient workplace and improve its safety by organizing the work area
	How dangerous is the physical access to the equipment that need to be maintained?	There is not any personal protective equipment or warning labels on the equipment or appropriate tools for safe working which makes the physical access to the equipment dangerous		

Figure 43 - Customer Compass Model (Safety, Health and Environment pillar)

b) Autonomous Maintenance (1 impact, 1 recommendation)

<table>
<tr><th>TPM Pillars</th><th>Questions</th><th>Causes</th><th>Evidence/Impact</th><th>Recommendations</th></tr>
<tr><td rowspan="3">Autonomous Maintenance</td><td>What is the percentage of employees that are performing maintenance and service activities? (outsourcing included)</td><td>When a problem occurs in a certain equipment it may not exist availability from maintenance employees to solve the problem quickly</td><td rowspan="3">The lack of employees working on maintenance and the lack of staff understanding regarding maintenance needs, can result in severe issues that affect the production process. These issues can be translated into the stoppage of the entire production line</td><td rowspan="3">Provide operators specific training regarding the Autonomous Maintenance of the TPM programme. The goal is to enable employees that operate the machines to perform some maintenance activities and to quickly predict abnormalities in the equipment, transforming them into a multi-tasked work force</td></tr>
<tr><td rowspan="2">What is your maintenance staff level of understanding the equipment? How accurate are them predicting deviations or abnormal performance of the equipment?</td><td>Workers are new to the job and do not had enough work time in the factory to properly know their own equipment</td></tr>
<tr><td>Operators are experienced but, they do have not been provided with adequate training to repair equipment when failure is not simple</td></tr>
</table>

Figure 44 – Customer Compass Model (Autonomous Maintenance pillar)

c) Quality Maintenance (2 impacts, 2 recommendations)

<table>
<tr><th>TPM Pillars</th><th>Questions</th><th>Causes</th><th>Evidence/Impact</th><th>Recommendations</th></tr>
<tr><td rowspan="5">Quality Maintenance</td><td>According to the criticality level of equipment, how do you monetarize them in order to prevent consequences in production?</td><td>The equipment is not monitored and the equipment that is operating poorly and that is more critical for the operation is not prioritized and do not receive proper</td><td rowspan="3">A defective product is identified only when it comes out of the production line, which means that the defect is now irreversible or very difficult to correct. If this is happening in a critical equipment, it means that the entire production from a certain period will be compromised</td><td rowspan="3">Install additional sensors like cameras or laser sensors that can be integrated and connected to the equipment in order to be able to track important process parameters as shape or weight of the production output, in order to identify deviations from the quality standards and avoid defects</td></tr>
<tr><td>Does the company have its own risk management system? How reliable is it?</td><td>Deviations regarding production quality occur and the equipment used is not well calibrated</td></tr>
<tr><td>Do you have deviations regarding production output or quality?</td><td>There is no control of the production quality in order to ensure that the output corresponds to the standards</td></tr>
<tr><td>How high is your quality rate in %?</td><td>The quality metric considers the quality loss, which accounts for produced pieces that do not meet quality standards, including pieces that require rework. It represents the machine or process yield of good parts as a percentage of the total parts produced</td><td rowspan="2">If the quality metric is low, it means that the number of defects is high. This could happen because the system is not stopped immediately when it deviates from the established range of tolerance which will lead to have a higher probability of a wider range of defective products. The fact that there are no control loops, the time required to understand exactly where the defect is being generated is higher. These situations can lead to low values in quality, high costs of rework, not fulfilment of due dates and, ultimately, the loss of customers.</td><td rowspan="2">Follow the Poka-Yoke approach, which enables to prevent mistakes from occurring, stop the error from further processing, and warn that the error has occurred. This will allow to detect in real-time if a defective part has been produced and stop the entire system immediately, in order to prevent more defects. The quality metric would increase dramatically with this approach, since the percentage of defective products would be highly reduced, following a zero-defects approach</td></tr>
<tr><td>Do you stop the system immediately when it deviates from the range of tolerance or is there any control loop?</td><td>When defective products are coming out in the end of the line, it is crucial to fast identify the reasons behind and avoid that the error repeats in a wider range of products. The best way to do it is to shootdown the system immediately and fix the problem. Control loops are useful to detect where the defect is occurring precisely</td></tr>
</table>

Figure 45 – Customer Compass Model (Quality Maintenance pillar)

d) Focus Improvement (3 impacts, 3 recommendations)

TPM Pillars	Questions	Causes	Evidence/Impact	Recommendations
Focused Improvement	On average, in percentage, how many times errors occur due to bad planning?	There is no available information in real time between the communication level and the different actors of the company	When there is not alignment between all the departments and activities of the value chain in order to make the entire process flow according to expectations, the entire process becomes compromised. Problems regarding capacity management, production line balancing and the achievement of previously set due dates may occur and could affect dramatically the company performance.	Creation of cross-functional teams and adoption of periodical meetings with assigned activities designed to minimize targeted losses that could be avoided by increasing communication and encouraging cooperation between different departments
	How close do production and planning work together? Are there any fixed procedures or periodical meetings?	There is lack of communication and cooperation between production and planning		
	How close do management (HQ) and production planning work together?	When there is lack of communication and cooperation between management and production, several problems may emerge		
	How close do the logistics and production work together?	When there is lack of communication and cooperation between logistics and production, several problems may emerge		
	In percentage, how many times do you run a root-cause-failure analysis when unplanned shutdowns occur?	When unplanned shutdowns occur, it is very important to understand the exact cause of the problem that originated the shutdown in order to prevent similar situations in the future	When it is not possible to know the performance level in real-time, there could be errors occurring in the process that are not easily detected, like false alarms or unplanned shutdowns. This fact influences the efficiency level of the process which can increase dramatically the operations costs and can lead to high rates of inefficiency to the process.	Document all causes regarding the requirement of unplanned actions or false alarms in order to understand them clearly. Precise controlling devices should be used in the system in order to easily assess performance levels, reduce the need to perform unplanned actions and false alarms to occur
	How often does any false alarm happen in the system?	When a false alarm happens in the system, it probably means that the controlling devices used are not enough precise or properly calibrated		
	How often do you check the production plant performance?	The performance indicator is directly connected with the efficiency level. If it is possible to assess the performance level in real-time, it is also possible to detect if something in the process is not flowing according to what is expected. With this, it is also easier to track the productivity and have the process documented in detail		
	Do you track your productivity? Is the production process reported and documented in detail?			
	How often should round trips occur in the plant?	Errors on operation are not so easily detected due to lack of supervision	The organization do not obtain the key vision of operators that play a central role in the process what could turn the company incapacitated to detect some issue in the process before it harms the entire process.	The Kaizen approach should be followed by implementing a system to collect problems identified by operators and their suggestions for improvement. Frequent round trips to the plant will enable to visually understand if processes are flowing accordingly and also will allow to get operators feedback in real-time regarding possible improvements
	How many ideas for improvement do you receive per ten employees per year?	There is a lack of operators' feedback that prevents the company from using specific operator's know-how to improve failures		

Figure 46 - Customer Compass Model (Focus Improvement pillar)

e) Planned Maintenance (4 impacts, 4 recommendations)

TPM Pillars	Questions	Causes	Evidence/Impact	Recommendations
Planned Maintenance	Do you have a life-cycle management system that supports the assessment of management and maintenance planning?	An integrated life-cycle management system in the plant, allows to identify the condition of the equipment in real time. This could allow to detect misfunctions in the equipment and solve them as soon as possible	If an integrated life-cycle management system is not implemented, it becomes very difficult to identify misfunctions in the equipment used in the plant before they become critical. It will also not be possible to continuously monitoring the status of the equipment in real-time and assess status reports. This fact can lead to unplanned shutdowns and serious impacts in the OEE value	A life cycle management system should be implemented and integrated. This will provide the required infrastructure to get all the analysis and reports from continuous monitoring and will allow to manage maintenance activities properly
	Do you have a management system for maintenance? How well is it integrated?			
	How do you assess the life-cycle status of your equipment?	The life-cycle management system, if well integrated, has the power to provide reports in real-time, making the assessment of equipment status very easy, which enables to take actions immediately		
	How often do you verify the working conditions of your equipment?	Continuous monitoring enables the assessment of information regarding working conditions of the equipment in real-time, allowing the equipment to continue operating. With this it is not necessary to stop the entire production line to verify the status of the machines		
	What percentage of time do you use to deal with unplanned actions?	Unplanned actions in maintenance are derived from unpredicted problems that require maintenance activities. Continuous monitoring condition of the equipments could play a central role in reducing the need to perform unplanned actions	If the number of unplanned actions is very high and the performance of the system is rarely monetarized or not monetarized at all, the metrics of OEE will be dramatically affected and it is very difficult to identify what are the equipment that need to be reviewed. Even if it is possible to understand which equipment will require maintenance, if the required products that measures different characteristics are not in place, it is not possible to identify exactly which is the problem and solve it. These situations do not allow to manage the components inventory in a lean perspective and could increases operational costs	Install sensors on equipment to stream vital stats in real-time and get information regarding future maintenance needs. This will allow to continuous monitoring the equipment status and take actions when necessary
	Do you know which are the next components that will require maintenance? How do you assess this information?	Continuous monitoring condition systems, allows to identify the condition of the equipment in real time. This could allow to identify exactly which components will require maintenance and to manage the inventory following a lean perspective		
	How do you monetarize the performance of the system?	There are several ways to monetarize the performance of the system. To have the possibility to assess it instantaneously in a remote manner, offers flexibility and saves time		
	How high is your availability in %?	The availability metric considers the net production hours divided by system schedule hours. If the availability metric has a low value, it means that the downtime is high. Unplanned downtime is derived by unexpected maintenance requirements	When the availability metric is low, it means that the company presents significant breakdowns or changeovers that could be avoided. It also means that the company do not follow a predictive maintenance approach which will disable the company to reduce asset failures cost-effectively. This can lead to not achieve due date promises since it becomes more difficult to minimize inventory and order parts well ahead of time to support the downstream maintenance needs.	Adopt a predictive maintenance strategy to maximize runtime, to care out repairs before a breakdown occurs and help to schedule maintenance activities to minimize overtime cost
	Which maintenance strategy is used in your plant?	A plant can follow three different maintenance strategies. Predictive, Preventive and Reactive. Despite it requires higher investment, Predictive maintenance allows to manage the entire maintenance process based on the actual condition of the machine instead of on some defined schedule		
	Do you test the system before bringing it back into operation?	When an equipment requires some intervention, it is crucial to test if it is 100% operational before bringing it back to the operation	If the equipment is not fully tested, it could still have some issues that were not identified which can lead to harm the entire operation	Test all the characteristics of the equipment before bringing it back to the operation in order to prevent from resulting into a shutdown and the need for performing several additional working steps after

Figure 47 - Customer Compass Model (Planned Maintenance pillar)

f) Training and Development (1 impact, 1 recommendation)

<table>
<tr><th>TPM Pillars</th><th>Questions</th><th>Causes</th><th>Evidence/Impact</th><th>Recommendations</th></tr>
<tr><td rowspan="3">Training and Development</td><td>What should be the ideal training time for maintenance people?</td><td rowspan="3">Maintenance people should receive regular training sessions in order to be updated about the required procedures to perform in different situations. They should not only learn the theory behind these procedures but test it also in a practical context as well, in order to ensure they are fully prepared to intervene when needed. With a well-structured training programme, the team would be able to perform maintenance activities faster and effectively, which would allow to reduce the time of response to solve issues that cause shutdowns</td><td rowspan="3">If maintenance people stay long periods of time without receiving proper training to update their skills, or the training is too theoretical, there could be some issues that they would not be able to solve, in the one hand because they do not know how, or in the other hand, because they only know the solution theoretically. This could lead to long shutdown periods and affect severely the OEE metric</td><td rowspan="3">It is important to regularly check the present status of education and training of the maintenance people. They must be updated and informed about the best procedures to solve any issue that occur in a fast and safe way. Prepare a training calendar regarding the main dimensions of the required maintenance activities and provide them with theoretical and practical regular training sessions</td></tr>
<tr><td>Are the conducted trainings more practical (hands-on) or theoretical (presentations)? Is there any test with a dedicated certificate after the training?</td></tr>
<tr><td>How is your time of response, on average, in performing maintenance activities that require to stop the system?</td></tr>
</table>

Figure 48 - Customer Compass Model (Training and Development pillar)

g) Office Improvement (2 impacts, 2 recommendations)

<table>
<tr><th>TPM Pillars</th><th>Questions</th><th>Causes</th><th>Evidence/Impact</th><th>Recommendations</th></tr>
<tr><td rowspan="6">Office Improvement</td><td>How long does it take (on average) from ordering a spare part until it is installed?</td><td rowspan="3">It is essential to ensure that spare parts are available and in good condition when required. For this, there should be in place a clear logistics process to ensure the deliveries and meet lead times. Contracts with not many different suppliers (1-3) should also be in place, in order to ensure an efficient coordination and quality control, avoiding, at the same time, the risk of stock out if one supplier fails</td><td rowspan="3">Since the most typical cause for stock out is the delay that may exist within the supply chain, it is important to ensure fast and reliable deliveries. If this does not exist and there is an incorrect order setting, a stock out can occur, which may lead to a plant shutdown</td><td rowspan="3">Just-in-time logistic process should be implemented in order to guaranty immediately deliveries before they are required and, this way, minimize storage costs. This implementation will also help in reducing the number of suppliers, which will increase the efficiency of spare-parts control and ensure that lead times fulfilled</td></tr>
<tr><td>How reliable are deliveries of spare parts? Is there any logistics process that guarantees deliveries?</td></tr>
<tr><td>How many suppliers of spare parts are involved?</td></tr>
<tr><td>Do you have an external service provider, who assists you in maintenance of spare-parts management?</td><td rowspan="3">Spare parts inventory control is a crucial topic regarding the success of the entire production process. There should exist spare parts buffers close to the production line in order to solve unexpected problems with the equipment and an external service provider that ensures that the spare parts are in good condition to be used</td><td rowspan="3">If spare parts are located far from the production line, it can lead to momentary stock out and, consequently to shutdowns. The same may occur if the spare parts to be used are not well maintained when it is required to install them</td><td rowspan="3">Outsource the maintenance activity of spare-parts in order to ensure the good condition of all the parts. Be sure to store the spare-parts near the production line in order to solve issues faster and avoid shutdowns</td></tr>
<tr><td>Do you store spare parts in the plant or off-site? How big is your spare parts stock?</td></tr>
<tr><td>What is the turnover ratio, regarding spare parts?</td></tr>
</table>

Figure 49 - Customer Compass Model (Office Improvement pillar)

h) Development Management (3 impacts, 3 recommendations)

TPM Pillars	Questions	Causes	Evidence/Impact	Recommendations
Development Management	How easily can the machine be optimized or retrofitted?	If possible, machines should be designed in a modular manner. This allows to easily optimize the performance of the equipment perfuming only small changes in the different modules and avoids the need to buy an entire new machine when an optimization is required. Modularization also allows redundancy in the implementation of automation equipment	When machines are not designed in a modular manner, it means that the implementation of the automation equipment can not be in a redundant way. In this context, if a certain part of a machine fails, the entire machine will collapse. This would require performing complex activities to solve the issue, forcing to a long shutdown of the entire system	Design the equipment in a modular way. This would allow to optimize the equipment easier by performing small changes in specific modules, to solve issues faster since when a problem occurs in a certain module of the equipment, only that module should be replaced, and to avoid long period shutdowns due to redundancy (if a certain part of the machine fails, the entire machine will not collapse)
	Is the automation equipment implemented in a redundant way for critical production processes?			
	Do you replace the existing equipment by the same technology or do you check for a state-of-the-art solution?	When the replacement of a certain equipment is needed, it is important to study the market and understand if there are new solutions and developments. In order to improve (lead or keep up) state-of-the-art solutions should be implemented. These are the solutions that offer greater performance, availability and quality. This is then a very important factor that can lead to the improvement of the OEE metric	In order to ensure the best performance of equipment, it is very important not only to replace equipment by state-of-the-art solutions when it is needed, but also to be frequently updated regarding new trends and regularly improve the production equipment. If these procedures are not done properly, it becomes very difficult to keep up with competition and impossible to lead, since the performance metric would be much lower than it should	Consider changing or update the equipment used in production. Search deeply and regularly for state-of-the-art solutions, this would make possible to keep up with competition or, in other cases, to lead the entire industry, by ensuring that the entire used production process is not obsolete. Organize trips to be present in industry fairs and communicate with partners to discuss new trends
	When was the last modernization of the automation equipment?	To remain competitive, not only it is important to look for new solutions and developments regarding the equipment used in production when it becomes obsolete, but regularly. If this process is performed periodically, the Company can be constantly updated regarding new solutions, and regularly update equipment with the most suitable solutions		
	How high is vour performance in %?	The performance metric considers the Performance Loss, which accounts for anything that causes the manufacturing process to run at less than the maximum possible speed when it is running		
	In percentage, how much do the installed components fulfill the required flexibility regarding changes in the production setup?	It is fulcral to ensure that the used components provides the required flexibility regarding changes in setup (for example when preparing the machine to produce a new line of products) and the requirements concerning low maintenance. Both factors allow to improve the efficiency of the production process, by reducing costs and production cycle time	If components are not flexible regarding changes in the production setup, or do not fulfill the requirements regarding low maintenance, it means, in the one hand that when a change of production is needed it will be required to perform complex activities in order to prepare the equipment to operate and, in the other hand, that if a problem occurs with a certain component, heavy operations to replace it will be required	Implement components that are both, flexible regarding changes in the production set-up and that fulfill requirements concerning low maintenance. This will allow the improvement of efficiency levels of the production process, reduce operations costs and production cycle time
	Does the current installed base fulfill requirements concerning low maintenance?			

Figure 50 - Customer Compass Model (Development Management pillar)