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Extended Lessons Learned framework applied to an automotive company

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A mia madre.
Alla sua forza,
al suo coraggio.

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List of Acronyms and Abbreviation

AIAG: Automotive Industry Action Group

AC: Alternating Current

APQP: Advanced Product Quality Control and Planning Plan

BEV: Battery Electric Vehicle

BMS: Battery Management System

BU: Business unit

CON: DC/DC converter

DC: Direct Current

EPT: Electric powertrain

EVs: Electric Vehicles

FMEA: Failure Mode and Effects Analysis

IATF: International Automotive Task Force

ICE: Internal Combustion Engine

ISO: International Organization for Standardization

JP: Japan

KPI: Key Performance Indicator

LL: Lesson Learned

LCL: Lower Control Limit

LSL: Lower Specification Limit

OBC: On-board charger

M-EPT: Marelli Electric Powertrain

MSA: Measurement System Analysis

N/A: Not Available

OEMs: Original Equipment Manufacturer

PDU: Power Distribution Unit

PDCA: Plan-Do-Act-Check Cycle

PMI: Project Management Institutes

PMBOK: Project Management body of Knowledge

PO: Process Owner

PPAP: Production Part Approval Process

QC: Quality Control

QI: Quality Improvement

QM: Quality management

QMS: Quality Management System

QP: Quality Planning

R&D: Research and Development

SPC: Statistic Control of Process

TGR: Things Gone Right

TGW: Things Gone Wrong

TO: Torino

UCL: Upper Control Limit

US: United States

USL: Upper Specification Limit

Introduction

The following report is the result of the candidate's experience at the company Marelli Europe S.p.a. based in Venaria Reale (TO), within the "Electric Powertrain" Business Unit, where the candidate had the opportunity to carry out a curricular internship lasting 350 hours and to continue her experience for completing the thesis work. During the internship, in the "Quality Strategy and Planning" area of EPT, the candidate, in addition to the main activity relating to the implementation of quality monthly reports, could participate in the QMS creation process, including IATF 16949:2016 certification process. Since continuous improvement is one of the basic aspects on which every quality management system is based, the candidate focuses on the Lessons Learned management system, currently under development. Historically, in M-EPT the LL management system is provided exclusively for the “product development” and “series production” processes. Consequently, the candidate's goal is to improve and to extend the current approach used by M-EPT to other QMS processes, by implementing a unique methodology that considers not only the technical aspects but also the systemic / managerial ones. The thesis is organized into 5 chapters.

In the first chapter, the candidate presents the company in general, focusing on the Electric Powertrain Business unit since the entire work will refer to M-EPT.

The second chapter deals with the theoretical aspects that the candidate takes into consideration during the implementation of the methodology under study. Within this chapter, the candidate reports a digression on the IATF 16949: 2016 standard and consequently an overview on the creation of the Quality Management System for automotive companies.

In the third chapter, which represents the main core of the thesis, the candidate's focus shifts to the Lessons Learned Management System. In addition to the extension and improvement of the “Bottom-up” methodology currently used in M-EPT, the candidate offers ideas for the achievement of Lessons Learned through a "Top-Down" methodology that sees the analysis of KPIs as a starting point.

In the fourth chapter, two case studies based on actual experiences in M-EPT will be dealt with, which are not subject to internal analysis (since they cannot be traced back to the processes of "product development" or "mass production"). In this chapter, the candidate's objective is to reconstruct the events and to apply the "Bottom-up" methodology to obtain possible Lessons Learned from the management point of view.

In the last chapter, advantages, limitations and future improvements of the proposed methodology will be analyzed.

1. Company presentation

1.1. Marelli historical background

Marelli was founded in 2019 through the union of Calsonic Kansei and Magneti Marelli. Today, the company is one of the most important independent automotive component suppliers globally. Marelli brings together two successful global automotive manufacturers from Italy and Japan, with a world-leading reputation for manufacturing excellence (Monozukuri) and innovation (Genba). Monozukuri is the Japanese term for 'manufacturing'. The term "Monozukuri" refers to something broader than the creation of products and can be considered as a real work philosophy that pushes towards manufacturing perfection and constant innovation. Also "Genba" is a Japanese word, it refers to the workplace, it is based on a set of improvements and technology innovation, carried out directly at the individual workstations. Marelli's position as a global player is rooted in the complementarity of the two companies both in terms of complementary production and in their geographical footprint.

Calsonic Kansei Corporation was a Japan-based manufacturer primarily engaged in the manufacture and sale of automobile components with 58 manufacturing centers spread throughout the United States, European Union, South Korea, Mexico, Thailand, South Africa, India, China and Malaysia. The company was born thanks to the merge of two existing companies: Calsonic Corp., specialized in air conditioners and heat exchangers, and Kansei Corp., a measuring instrument manufacturer. During its 80 years of history, Calsonic Kansei grew its operations across Asia and Europe to become a leading player in the field of Interior Experience (Cockpit Modules/Interiors), Climate Control Systems, Heat Exchange and Compressors.

Magneti Marelli was founded in the 1900's with the name F.I.M.M. (Fabbrica Italiana Magneti Marelli) because of a joint venture between Ercole Marelli and Fiat. Its first plant was founded in the outskirts of Milan, in Sesto San Giovanni, producing magnets for aviation and internal combustion engines for cars and motorcycles.

After an initial period in which the production was based exclusively on car components, the company opens offices in Paris, London and Brussels, diversifying production from lighting and sound warning systems for vehicles, up to the creation of RadioMarelli and Fivre (Italian Radio Electric Valves Factory). After going through a period of crisis during the Second World War due to the bombings that destroyed some of the most important factories, Magneti Marelli revived its fortunes in 1967 becoming part of the Fiat Chrysler Automobiles group. During its 100-year history, it served customers from its base in Italy, growing operations across Europe, North and South America, India and China until it became a leading player in the field of Lighting, Electronics, Powertrain and Motorsport.

1.1.1. Logo Marelli

Marelli logo, officially disclosed in 2019, has its roots in the long history of innovation and manufacturing excellence of the companies, it includes indeed the corporate colors from Calsonic Kansei (light blue) and Magneti Marelli (dark blue). The logo is formed by two geometric shapes which symbolize the company's engineering precision and technological know-how. In addition, the two shapes look like two upward-pointing arrows, symbolizing progress and future, while their union signifies the combination of two powerful companies coming together as partners in a collaborative spirit.

Figure 1: Logo Marelli

1.1.2. Marelli business units

With around 60,000 employees worldwide, Marelli footprint includes 170 plants and R&D centers across the major countries (see figure 2) around the globe.

Figure 2: Marelli presence in the world

Marelli is divided into different business areas, whose main values reflect the corporate strategy of transforming the future of mobility through constant innovation, environmental sustainability and manufacturing excellence. The main product areas can be classified into:

- *Automotive lighting*
- *Electronics*
- *Powertrain*
- *Thermal Solution*
- *Cabin Comfort*
- *Green Technology System*
- *Interior Experience*
- *Ride Dynamics*

- *Motorsport*
- *Electric Powertrain*

1.2. Focus on Marelli Electric Powertrain

The curricular internship supported by the candidate took place within the Electric Powertrain Business Unit. Consequently, the entire thesis will refer to the research activity only within the Electric Powertrain BU.

After decades in which the traditional internal combustion engine has been the dominant automotive powertrain, the automotive industry is experiencing one of the greatest social, technological, and economic transformation; shaped by four key disruptive forces: electric vehicles and alternative powertrains, connected vehicles, on demand mobility services and autonomous driving. The motivations behind the exponential adoption of electric vehicles and the consequent expansion of the EV market can be summarized in three main driving forces:

1. Change in customers' needs and behaviors: the growing awareness of consumers' environmental sustainability has led to a change in purchasing behavior increasingly based on the adoption of "sustainable vehicles"

2. Regulations: Regulations themselves are operating along three main directives:
    - CO_2 reduction, with limits that force OEMs to introduce progressively electrified vehicles to diminish the average carbon emissions footprint
    - Prohibitions of transit in large metropolises for non-electric vehicles during specific time slot
    - Incentives for the purchase of electric vehicles

3. Decrease of cost-related barriers for the adoption of electric vehicles: Deloitte estimates that the market will reach the tipping point in 2022, when the total cost of ownership of BEV is on par with its internal combustion engines counterparts. (Deloitte,2019)

Within this framework, Marelli Electric Powertrain (from now on M-EPT) is focused on delivering solutions (based on energy optimization, cost and performance efficiency) that help automotive OEMs projects to win the difficult challenge represented by the new sustainable mobility. Pursuing the corporate values of innovation and sustainability, M-EPT has been a pioneer in electrification: Marelli Motorsport unit created the first F1 K.E.R.S.(Kinetic Energy Recovery System), i.e. the first hybrid solution in Formula 1, back in 2009. From that moment on there has been a continuous technology transfer from race (F1, Formula E) to road. Moreover, M-EPT has been also the first to develop an 800V system that has been put in production in a successful premium car. This system enables quicker DC fast charging versus conventional 400V systems, to meet the demands of customers who are looking for ever faster battery charging times to avoid long queues and / or delays at charging stations.

As shown in figure 3, Marelli-EPT Research & Development centers, Applied Research centers and production plant cover each major region of the globe.

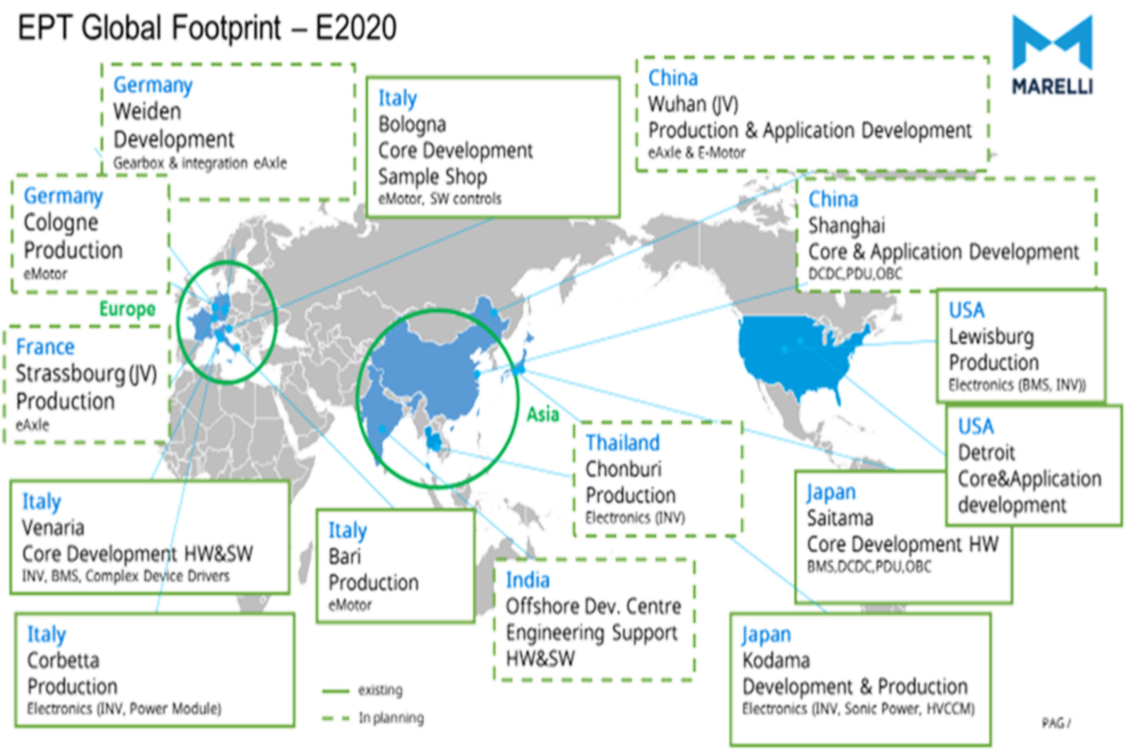

Figure 3: M-EPT Global Footprint

1.2.1. Marelli EPT Key Products

M-EPT in-house laboratories, product testing and validation facilities are one of its greatest strengths, giving the ability to control all phases of product development. Among the key products of M-EPT, the most relevant are (see fig.4):

- *Inverter*
- *Electric Motors*
- *E-Axle*
- *Battery Management System (BMS)*
- *Power Electronics (DC/DC Converter, OBC, PDU)*

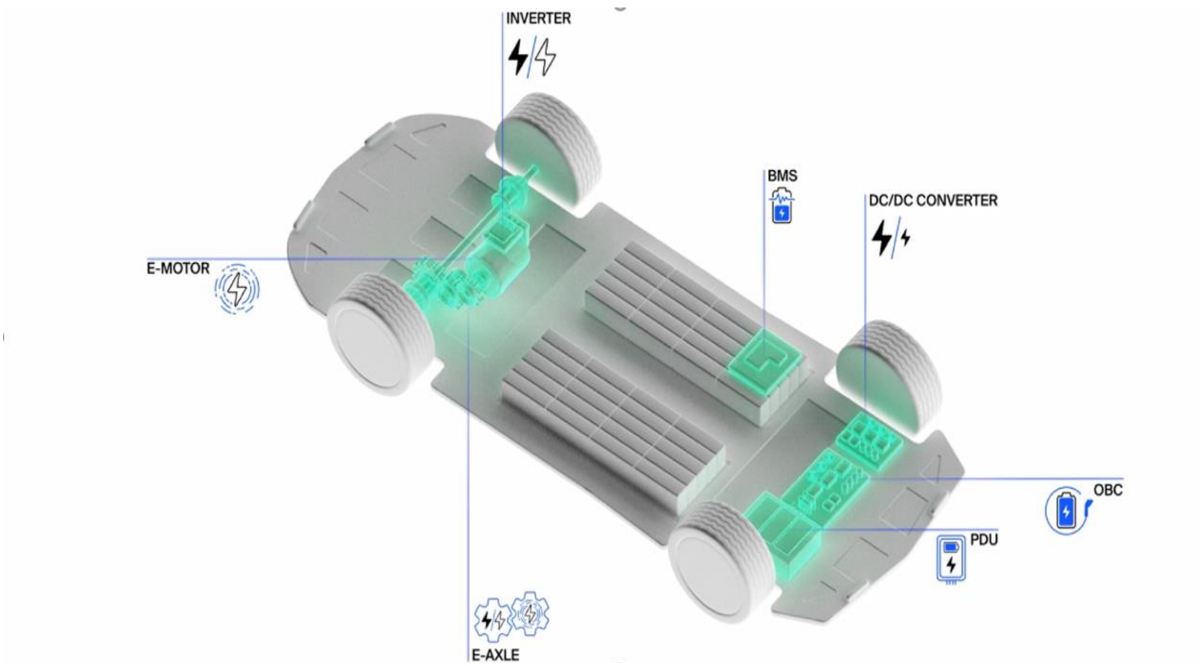

Figure 4: M-EPT Product range

- *Inverter*: it is an electronic component that has the function of transforming a DC into AC at a certain voltage and frequency, using a direct current source. M-EPT is one of the most experienced manufacturers of mass production traction inverters and it manufactures inverters in every major market (JP, US, Europe, South Asia), this provides the capability to serve global customers, guaranteeing a constant quality level worldwide. The current inverter product portfolio boasts a wide range of state-of-the-art inverter designs ranging from 48V to 800V(see fig.5).

Figure 5: M-EPT Inverter current product portfolio

- *Electric motors*: devices that convert electrical energy into mechanical energy, usually using electromagnetism. Working for top cars and premium car brands, M-EPT gained a relevant specialization in high performance e-motors, both in 400V and 800V technologies. The knowledge acquired with these top cars applications has now been transferred to a complete range of products capable of covering most of the OEMs needs.

Figure 6: M-EPT E-motor current product portfolio

- E-Axle: it is a complex system at the heart of the powertrain of every BEV or Plug-in Hybrid. Marelli 30 years' experience in series automotive mechatronics, its solid track record on e-motor and inverter designing, developing and manufacturing combined with the mechanical knowledge and precision of gearboxes are the special ingredients at the base of Marelli E-axles. In fact, it incorporates all M-EPT key competencies.

Figure 8: M-EPT E-Axle

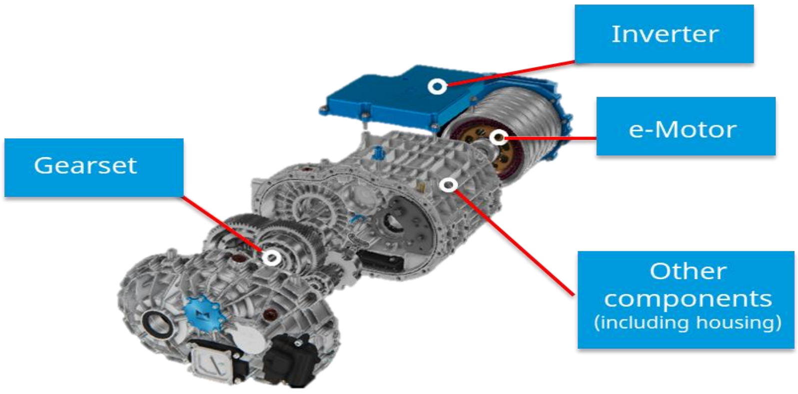

Figure 7: M-EPT E-Axle Architecture

- *Battery Management System:* Marelli Battery Management System (BMS) has the purpose to control high voltage batteries (up to 800V systems). Marelli offers solutions for any customer need, providing two different architectures: integrated and distributed

Figure 9: M-EPT BMS

- *Power Electronics*: Power electronics components (Power Distribution Unit (PDU), On-board charger (OBC) and DC/DC converter (CON)) complete Marelli EPT offers creating a unique fully integrated solution for managing the complete flow of energy in a vehicle

2. Theoretical Concepts

2.1. Introduction to Quality

Quality is crucial to the long-term success of a business. Although there is no common definition for the word "Quality", this concept has undergone several transformations over time, in parallel with the changes and evolution of environmental reality and context (Franceschini F,2001)[1]. The first hints on the definition of quality are dated back to the 1920s; before those years, its meaning was linked to that of testing. After the World War II, Japan began to talk about quality in a systematic way, as an instrument that allowed the nation to recover from the deep economic crisis. Quality for Japanese became an instrument of revenge after the war. However, it was not the quality of products that the Japanese industry obtained (considering the canons of the industrial culture of the time), it was the quality of processes and production instead, since they became able to generate better products at lower costs. It was in those years that the "Japanese model" began to mature: according to this model, respect for technical specifications was no longer enough, it was necessary to think also of organizational specifications. Even in the United States there were precise data on the importance of the quality factor on market shares and profit levels, but the information available was not yet able to motivate a considerable breakthrough in the mind of top management. Thanks to the Japanese competition, the companies wondered what the distinctive characteristics of these products were and how it was possible to reach their quality standards. Therefore, it was only at the beginning of the 80s that the management began to consider the importance of quality for the success of companies.

In its broader meaning, the term "quality" can be clustered in two categories (Vivek Nanda, 2005):[2]

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[1] F. Franceschini(2001): "Advanced Quality Function Deployment", St Lucie Press
[2] Vivek Nanda(2005): "Quality management system handbook for product development companies", Crc Press

1. Quality is about satisfying applicable specifications. Quality is a simple matter of producing products or delivering services whose measurable characteristics satisfy a fixed set of specifications that usually are numerically defined
2. Quality is about satisfying the customer. Regardless of any of their measurable characteristics, quality products are simply those that satisfy customer expectations as a result of their use or consumption

Hence, product or service performances are strictly related to customer satisfaction. Therefore, quality management plays a crucial role in the growth and performance of the business. The latter is also essential to ensure that the end customer can benefit from a reliable, long-lasting and standard-compliant product. By improving product and/or service quality, companies will be able to improve their reputation, grow customer loyalty and enjoy stronger performance. In general, for a company, improving and spreading the culture of quality represents one of the factors by which the company manages to differentiate itself from its competitors.

2.1.1. Quality Management

Before going into the detail of the description of the Quality Management System, it is important to take an overview on the quality management topic. It is possible to define Quality Management as follows: "Quality management comprises all activities that are required to plan for quality in an organization, and all the activities that are required to satisfy quality objectives." (Vivek Nanda, 2005). These activities include the determination of a quality policy, creating and implementing quality planning, quality control and quality improvement. To better understand the characteristics of each of these activities, reference will be made to the Juran Trilogy, also called the Quality Trilogy. The underlying concept of the quality trilogy is that managing for quality consists of three basic quality-oriented processes (J.M. Juran,1986)[3]:

• Quality planning process

[3] J.M Juran , 1986 – "The Quality Trilogy, A Universal Approach to Managing for Quality". Juran Institute, Inc., Wilton, CT

• Quality control process

• Quality improvement process

The above three basic principles have different objectives and serve different purposes of Quality Management; they must “travel” in parallel, guided by cost controls.

The quality planning (QP) process and its associated methods, tools, and techniques have been developed for designing products (both goods and service) not only to fulfill the technical requirements, but also to meet the needs of the customer who will purchase the final product.

Quality control (QC) is a management process universally adopted for carrying out operations and has the function of guaranteeing the satisfaction of both the requirements set by international standards and those set by the company. Reporting the definition according to J.M. Juran, "the quality control process evaluates actual performance, compares actual performance with objectives and acts on the difference" (J.M. Juran, 1986). Consequently, from a business viewpoint, quality control has the ultimate goal of checking and inspecting the finished product so that it complies with the pre-established requirements and making corrections and improvements where necessary.

Quality Improvement (QI) can be described as the set of all approaches using short-term results to improve performances, while adopting a long-term view. Moreover, the role of quality improvement is to continuously monitor performance, both in relation to established performance levels and to find new areas for improvement, adapting individual processes to changes in the external environment. Due to its relevance in this work, continuous improvement through the adoption of Lessons Learned tool, will be dealt in the following chapters.

Table 1 shows, in abbreviated form, the sequence of steps for each managerial process.

Table 1: The three processes of managing for quality [from Juran,1986. The Quality Trilogy: A universal approach to managing for quality. Juran Institute, Inc., Wilton, CT]

Quality Planning	**Quality Control**	**Quality Improvement**
• Establish quality goals • Identify the customers: both external and internal. • Determine customer needs. • Develop product (good and service) features that respond to customer needs. • Develop processes that can produce the needed product features. • Prove process capability—prove that the process can meet the quality goals under operating conditions.	• Evaluate actual performance • Compare actual performance with quality goals • Act on the difference	• Prove the need • Establish the infrastructure • Identify the improvement projects • Establish project teams • Provide the teams with resources, training, and motivation • Establish control to hold the gains

The three processes of the Juran trilogy (Quality Planning, Quality Control and Quality Improvement) are connected in the so-called Juran Trilogy Diagram (Fig. 10 shows this interrelationship).

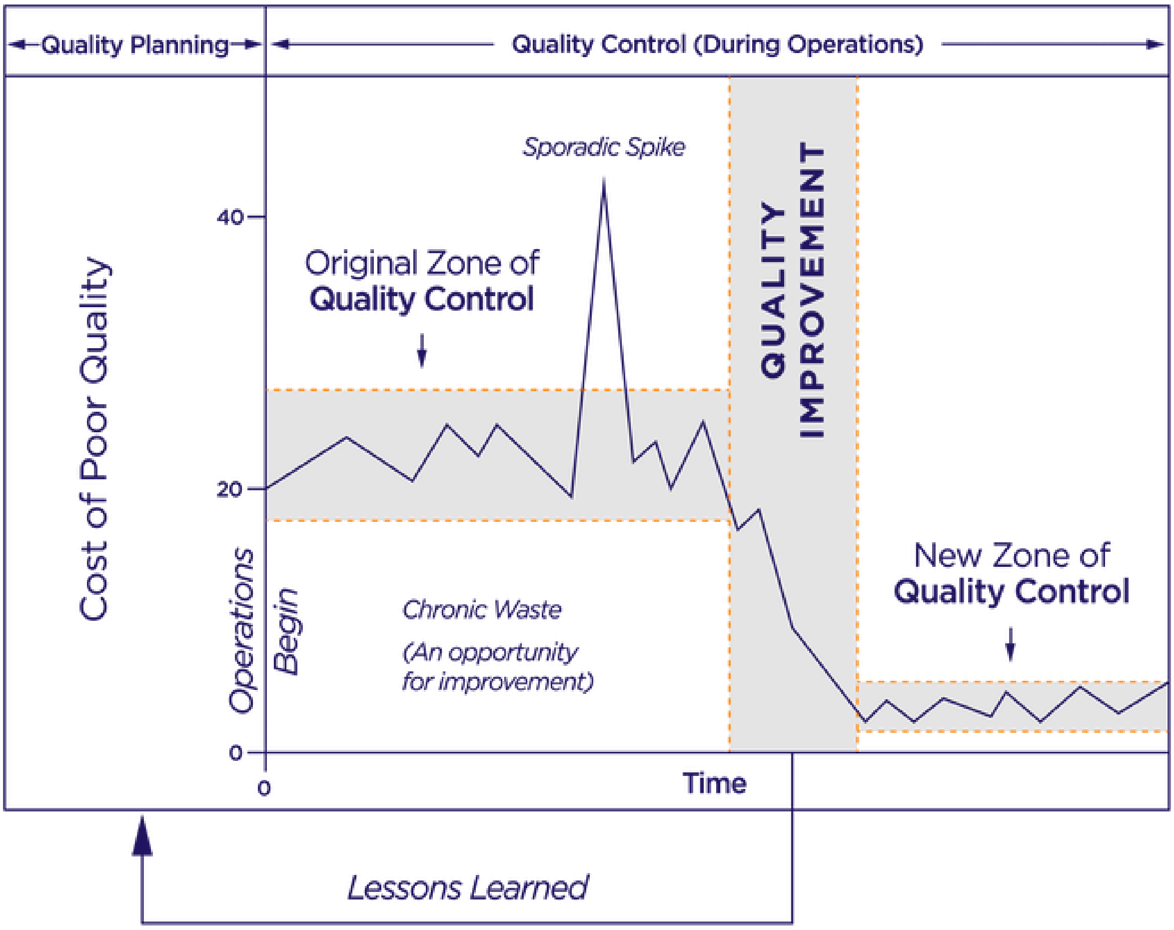

Figure 10 : Juran Trilogy Diagram

The starting point is quality planning, through which it is possible to develop new products, both goods and services, that meet the customers' requirements. As operations proceed, the process is turned over to the operating force with the aim to run the process at optimal effectiveness. In this stage, it is possible to notice that the products delivery is not 100 percent defect free. Due to failures in the original planning, the process works with a high level of chronic waste: more than 20% of the work has to be redone. This waste is considered chronic as it continues until the organization decides to find the root causes and to remove it. Although such waste was planned in the process; operational forces cannot bring the scrap level to 0. Consequently, by implementing the principle of "quality control" it is possible to ensure that the percentage of rejection does not deteriorate. However, as shown in the figure above, a sporadic spike (more than 40% of waste) might arise due to unplanned events and from various unexpected sources. Once the causes have been determined, and corrective actions are taken, the process again falls into the zone defined by the "quality control" limits, reducing the chronic waste to about 5 percent. The gain came from the third process in Juran Trilogy: Quality Improvement. Through this phase it is possible to notice that already the drastic reduction of waste is an improvement in terms of quality. Finally, the graph shows an arrow connecting the Quality Improvement process with the Quality Planning, through the Lessons Learned. Project Management Institutes (PMI) and Project Management body of Knowledge(PMBOK) defines the Lessons Learned as the learning gained from the process of performing the project. They may be identified at any point during the lifecycle of a product, and they are useful to help the project team to share knowledge, gained from past experience. This topic will be broadly debated in the next chapters, where a new method for managing Lessons Learned will be presented.

2.1.2. Quality Tools

Dr. Kaoru Ishikawa, guru of total quality management, identified 7 basic quality tools, which can assist an organization for problem solving and process improvements (Neyestani, Behnam, 2017)[4]. The seven analyzed quality tools are as follow:

- Flow Chart
- Check Sheet
- Histograms
- Pareto Charts
- Cause-and-Effect Diagrams (Ishikawa diagrams)
- Scatter Diagrams
- Control Charts

[4] Neyestani, Behnam (2017). "Seven Basic Tools of Quality Control: The Appropriate Techniques for Solving Quality Problems in the Organizations"

Flow Chart

A Flow Chart is a diagram that defines the evolution of an operation, process or compute algorithm. Each step is displayed through a series of standard symbols (such as rectangles, diamonds, or ovals) connected by arrows, which define flow and sequence. "The Flowchart, as a problem-solving tool, can apply methodically to detect and analyze the areas or points of process may have had potential problems by "documenting" and explaining an operation, so it is very useful to find and improve quality into process" (Neyestany, Benham, 2017. From Forbes and Ahmed, 2011).

Check Sheet

The Check Sheet is a simple but effective tool used for data collection and analysis, within an organization. Furthermore, through the tabulation of the data it is possible to evaluate the frequency of the occurrence of a problem in a given period of time. The data is recorded by making marks in the cells (if there is a correlation between the defect type and the event occurrence), that will be analyzed by observing both their position and their number.

Defect Types	No of occurences				
	Monday	Tuesday	Wednesday	Thursday	Friday
Wrong Orders	I			III	I
Late deliveries		II		I	III
Reworked Orders	III		II		
Shipping damages				III	II
Late Payments		I			I
Missing Label	III			I	
TOTAL	7	3	2	8	7

Figure 11:Check Sheet example

Histogram

Similar in appearance to a bar-chart, the histogram is the most used graph to show frequency distributions. The histogram condenses a data series into an easily interpreted visual, by grouping a range of outcomes into columns along the x-axis. Whereas, the y-axis can be utilized to describe data distributions, since it is possible to represent on each column, the number count or percentage of occurrences. For each value of the x axis, a basic rectangle proportional to the width of the class and a height proportional to its frequency is matched. If the rectangles are juxtaposed, we speak of a histogram; if they are separated, we speak of a bar chart. (G. Serpelloni, E.Simeoni, L. Rampazzo, 2002)[5]

Pareto Chart

The Pareto Principle, also known as 80/20 Rule, was developed by a well-known Italian economist, Vilfredo Pareto, who observing that a relative few people held most of the wealth (20%), developed a logarithmic mathematical model to describe such non-uniform distribution. Some years later, Dr. Joseph Juran was the first to point out that Pareto observation was a “universal” principle: the 80% of effects arise from 20% of the causes. The Pareto Chart is an excellent visual example of the application of the 80/20 principle. As shown in figure 5, it is composed of a histogram (in which the height of the bars represents the number of each category) and the Lorenz curve which defines the cumulative distribution. Plotting the determining factors of a given phenomenon on the horizontal axis and their percentage incidence on the vertical one, it is possible to identify the categories that require priority intervention. The Pareto analysis

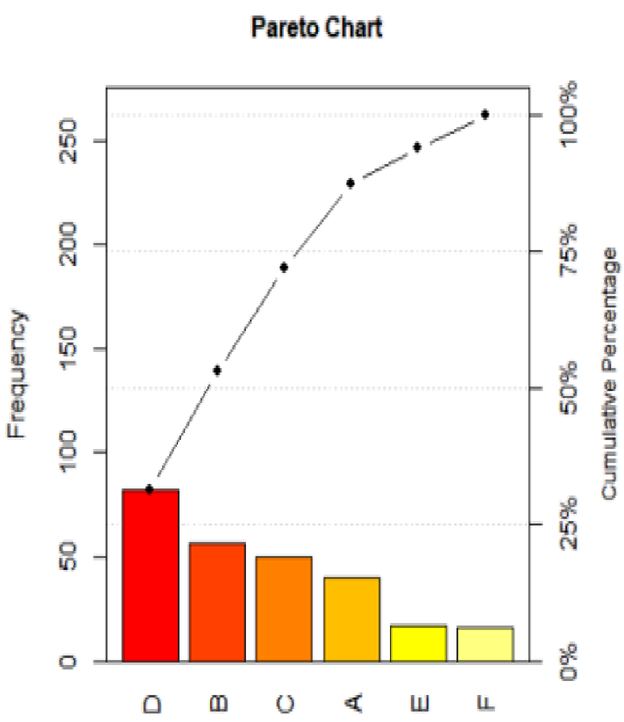

Figure 12: Pareto chart example

[5] G. Serpelloni, E.Simeoni, L. Rampazzo, 2002. “Quality Management. Indicazioni per le aziende Socio Sanitarie e il Dipartimento delle Dipendenze.”

also allows an immediate verification of the effectiveness of attempts at improvement. In fact by comparing two representations of the same phenomenon, before and after the intervention, there is an immediate display of the progress made and a measure of overall improvement, which is normally also reflected in a change in the order of importance of features (G. Serpelloni, E.Simeoni, L. Rampazzo, 2002).

Ishikawa Diagram

Ishikawa diagrams, also known as cause-and-effect diagrams or fishbone diagrams, are tools developed by Kaoru Ishikawa during the 1960s to identify the most likely cause of an effect or problem. The fishbone diagram, as suggested by the name, shows the problem at the head of the fish-like looking diagram and a backbone with major factors that can bring success or failure to the process, as the major bones attached to the backbone. One of the first steps in creating a fishbone diagram is determining the factors that contribute to variations within a process. Ishikawa describes these contributing factors as the 6 Ms in the manufacturing world: man, machine, method, material, measurement and Mother Nature. These 6 Ms influence variation in all processes and serve as the first six main “bones”.

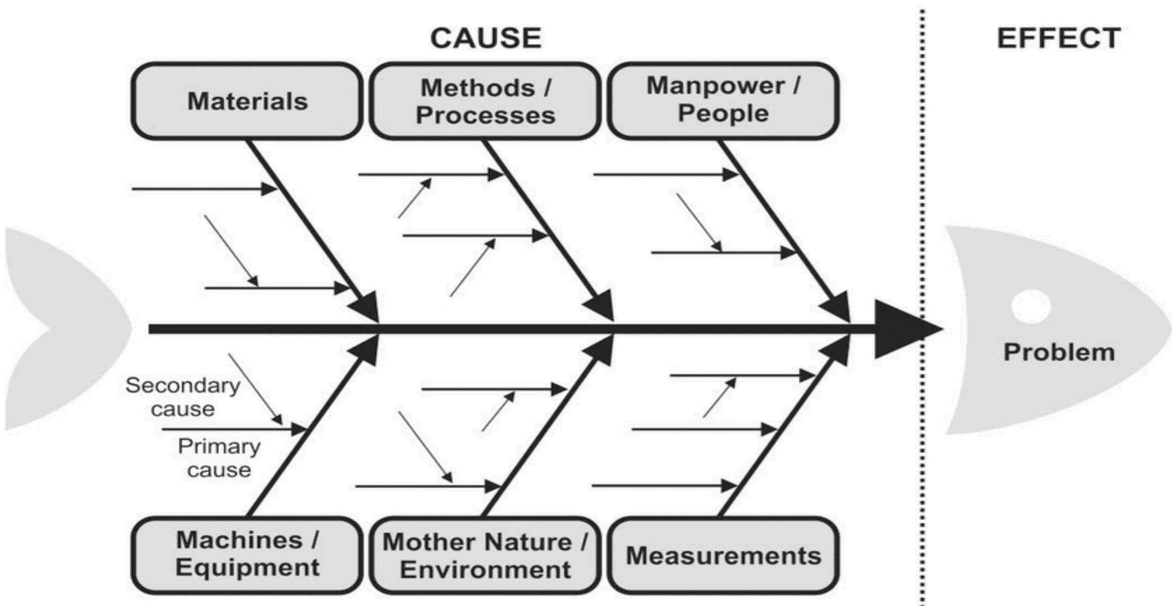

Figure 13: Ishikawa diagram

Each of the major factors has additional bones attached to that category, that outline the cause-and-effect relationship that may be causing the problem. It is possible to use many techniques to develop a cause-and-effect relationship, but one of the most used technique in business contexts is the 5-Why type questioning process to create the cause-and-effect bone structure.

Scatter diagram

Scatter diagram, also known as correlation diagram or X-Y graph, is a graph composed of an independent variable (common cause) on the X-axis and a dependent variable (effect) displayed on the Y-axis. The data are displayed as a collection of points, each having the value of one variable determining the position on the horizontal axis and the value of the other variable determining the position on the vertical axis. The aim of the scatter diagram is to show the relationship between the two above mentioned variable. The relationship, also called "correlation" can be positive (both variables move in the same direction), negative (the variables move in opposite direction) or could not exist.

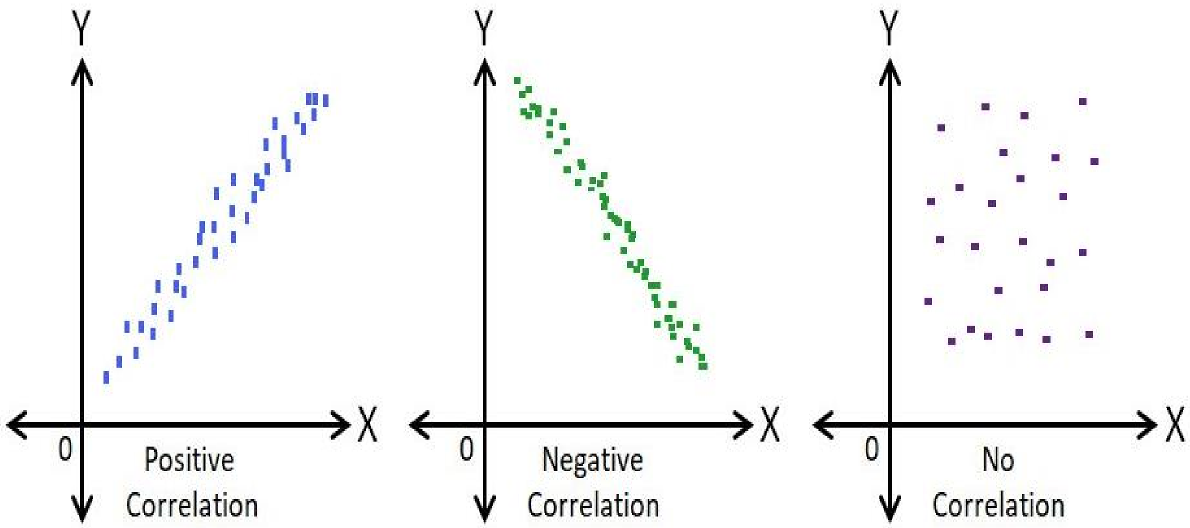

Figure 14:Scatter Plots & Correlation examples

Control Chart

Control charts are statistical process control tools used to evaluate if a process is in a state of control or if it is affected by special causes that determine its variation (not attributable to natural process variation (common causes)). Depending on the type of data, the control charts are divided into: variables control chart (used when the variable under consideration can be measured on a continuous scale) and attribute control charts (used for discrete variables). In general, a control chart is divided into 6 areas delimited by well-defined values:

- Upper Specification Limit and Lower Specification Limit:
  USL and LSL are specification limits defined by the contract with the customer. Beyond these limits the product no longer conforms to the required specifications

- Upper Control Limit and Lower Control Limit:
  UCL and LCL are limits within which the process can be defined as being in control. If a measurement exceeds these limits, corrective actions are required. Normally if the measured parameter has a Gaussian distribution, these limits correspond to values 3σ distant from the center line, which represents the average value of the distribution.

- Center Line (CL) represents the average of the process in control.

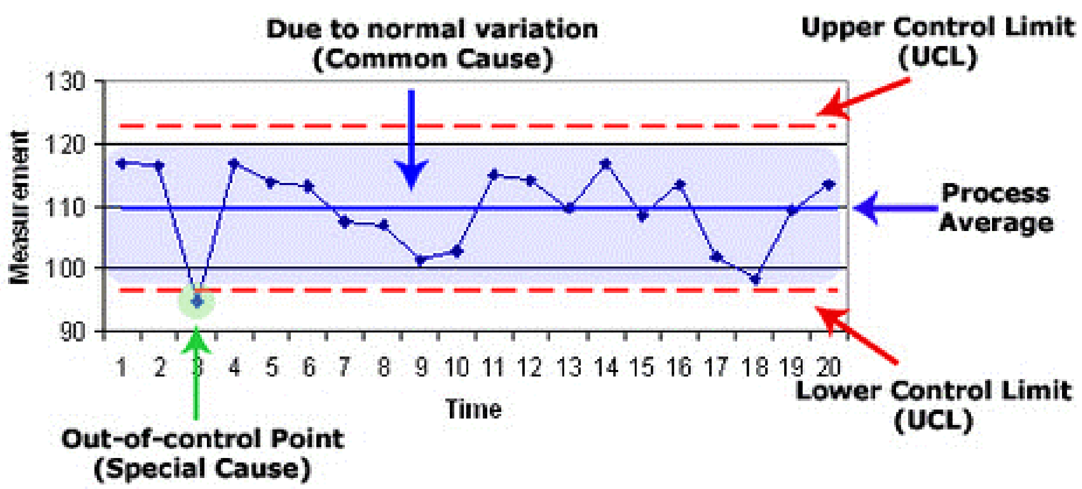

Figure 15: Control Chart example

For the methodology proposed in the next chapter to be consistent with the requirements specified in the QMS standard, it is essential that the quality tools above outlined are consistent with the PDCA methodology. The latter, being one of the fundamental pillars on which a Quality Management System is based (as specified in the ISO 9001: 2015 standard), will be further explored later. For this purpose, the table below shows the correlation between the seven quality tools and the PDCA cycle.

Seven basic quality tools (7QC tools)	Steps of PDCA-cycle				
	Plan	Do	Plan, Check	Plan, Act	Check
	Problem identification	Implement solutions	Process analysis	Solutions development	Result evaluation
Flow chart	✓			✓	
Cause-and-effect diagram	✓		✓		
Check sheet	✓		✓		✓
Pareto diagram	✓		✓		✓
Histogram	✓				✓
Scatter plot			✓	✓	✓
Control charts	✓		✓		✓

Table 2: Correlation between 7Q Tools and PDCA: Adapted from PRACTICAL APPLICATION OF QUALITY TOOLS,2018

2.2. IATF 16949:2016 – QMS in the automotive industry

As highlighted in the previous paragraphs, since there is no univocal definition of quality, it is necessary to adopt a standard to obtain an objective assessment of quality management. “The quality management standard includes guidelines and recommendations for the quality management system, the latter in turn includes the organizational structure of the company, the processes, procedures and other means necessary for successful quality management" (Pavletić, Soković, Paliska, 2008)[6]. Today "the automotive Quality Management System is based on the IATF 16949:2016 standard which focuses mainly on processes and customer satisfaction (intermediate or ultimate); and by which both employees and suppliers are involved" (Goicoechea & Fenollera, 2012)[7]. In general terms, IATF 16949:2016 (replaces ISO / TS 16949:2009) is a standard that establishes the requirements and clauses for building a Quality Management System, specific for the design, development, production, assembly and installation of automotive products; including products with embedded software. Furthermore, it is an independent standard but fully aligned with the structure and requirements of ISO 9001:2015 which are no longer present in the document. In fact, IATF 16949:2016 contains only the additional requirements specific for the automotive sector. Therefore, automotive companies, wishing to obtain IATF 16949:2016 certification, must comply with the requirements and clauses provided by both standards. Some key differences that can be found between the two standards are:

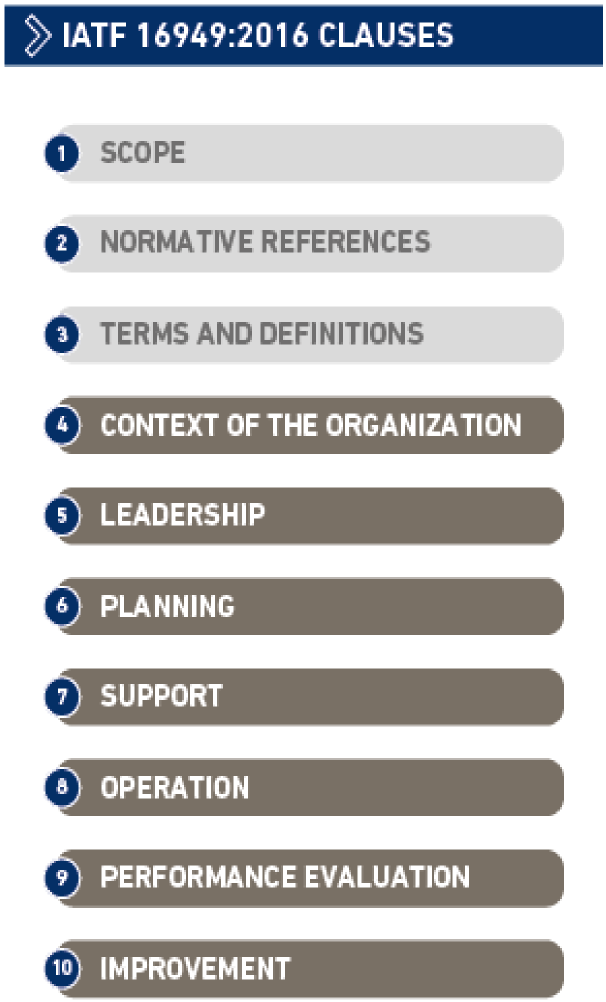

Figure 16: IATF 16949:2016 Clauses

- ISO 9001 is aimed at any type of organization (both public and private) while IATF 16949:2016 is aimed exclusively at organizations in the automotive field. Consequently, the latter has specific clauses for the given field of application

[6] Pavletić, Soković, Paliska, 2008. International Journal for Quality research. "Practical Application of Quality Tools"

[7] Goicoechea & Fenollera, 2012. Daaam International Scientific Book 2012. "Quality Management In The Automotive Industry"

- ISO 9001 can be implemented as a standalone document, while IATF needs to be combined with the ISO 9001 standard

- ISO 9001 focuses on satisfying customer satisfaction, while IATF focuses on satisfying both technical and CSR requirements, i.e. the requirements agreed between supplier and customer.

Since compliance with quality standards is one of the fundamental pillars on which the success of many automotive companies is based, through the implementation of a Quality Management System, the organization demonstrates its ability to provide standard-compliant products that meet customer requirements. In this way, it will be possible to acquire new customers and enter new markets. For an organization to be certified according to the IATF 16949 standard, it must make use of an external certified body that will verify that the clauses (see figure 16) contained in the standard are fully documented and applied within the organization. In general terms, the clauses highlighted in the figure are based on the 7 principles of quality management, illustrated in detail in the next sub-paragraph.

2.2.1. Quality Management System Principles

A Quality Management System is defined as a formalized system that documents processes, procedures, and responsibilities for achieving quality policies and objectives. A QMS helps to coordinate and to direct an organization’s activities to meet customer and regulatory requirements. Moreover, it improves company’s effectiveness and efficiency on a continuous basis. A QMS integrates the various internal processes within the organization and it intends to provide a process approach for project execution. A process based QMS enables the organizations to identify, measure, control and improve the various core business processes that will ultimately lead to improve business performance. The nature of the organization and the specific challenges it faces will determine how to implement its QMS. To establish an effective Quality Management System, an organization must follow the requirements provided in the figure below (see fig. 17).

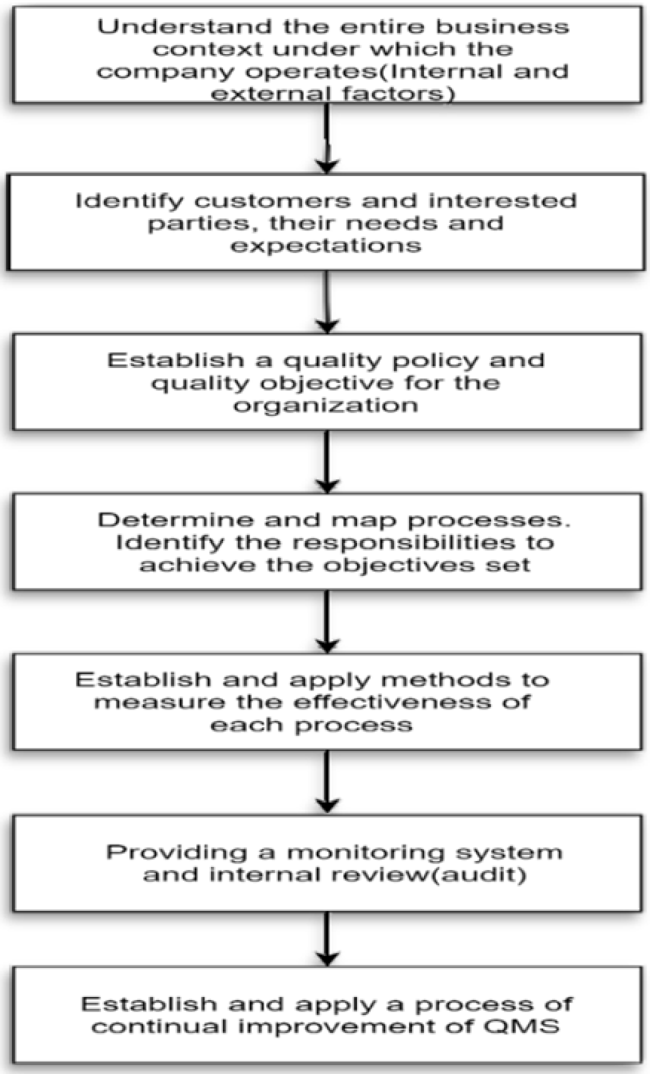

Figure 17: Steps for implementing a QMS

The first step for the implementation of the QMS, according to the automotive standard, is to have a well-defined overall picture of the current situation of the company and to have a good knowledge of the requirements specified by the standard. For an organization to implement a QMS and be certified, it must prove to a certifying body that it has implemented and documented all the requirements set forth by the IATF 16949:2016 standard. In this regard, the organization can make use of an external expert consultant. The organization must be aware of the internal and external context in which it works, which means to identify who the interested parties are and what the qualitative objectives it intends to pursue are. Once the business context has been established, the organization must identify and map which processes and policies are in force in the company. Then, following the principle of leadership, the quality policy will be defined, by assigning responsibilities, roles, and authorities. All that is needed to support the processes is then defined, in terms of technical, human and competence resources. Once the quality management system is in place, it must be monitored and evaluated. In this way it will be possible to observe and document the degree of compliance of the organization with respect to the planned objectives. The last step concerns improvement, i.e. making the necessary changes to regulate the system, if discrepancies with the planned objectives were identified.

Through the Automotive Quality Management Standard, it is possible to define, in conformity with ISO:9001, seven QMS basic principles which form the background to the entire process of creating the Quality Management System (fig. 18).

Figure 18: Quality Management principles

1) *Customer focus*: The first principle is that a company would not exist without its customers. Moreover, even the definition of quality itself is closely linked to customers' satisfaction. Customer focus includes the need to understand current and future customer needs and to meet customer requirements while exceeding expectations.

2) *Leadership*: “Leaders at all levels establish unity of purpose and direction and create conditions in which people are engaged in achieving the organization’s quality objectives” (ISO, Quality Management Principles). Hence, the role of the leadership in the QMS system is to create a united working environment, by guaranteeing unity of purpose and involvement of people, to allow the alignment of strategies, processes and policies in order to achieve the company objective.

3) *Engagement of people*: “Competent, empowered and engaged people at all levels throughout the organization are essential to enhance its capability to create and deliver value” (ISO, Quality Management Principles). Since the company's long-term success also depends on its employees, they must be competent and add value to the organization. The standard establishes that this principle is based on respecting the employee first and foremost as individuals. Their involvement is therefore essential to achieve the set business objectives and for the success of the strategies

4) *Process approach*: the QMS is based and composed on interrelated processes. Therefore, processes become the main element of the organization which no longer consists of single units. The process approach allows to focus on the results of the entire organization and not on the work of individuals. Understanding how the results were produced by the system, including processes, resources, control and interactions, makes it possible for the organization to continuously improve its performance

5) Continuous improvement: “Improvement is essential for an organization to maintain current levels of performance, to react to changes in its internal and external conditions and to create new opportunities.” (ISO, Quality Management Principles). According to the International Organization for Standardization, “continual improvement should be a permanent objective of the organization”. There are many important advantages that can be brought by continual improvement, as a performance advantage obtained thanks to better organizational skills and an alignment of strategies based on the continuous satisfaction of stakeholders. Continuous improvement, also focusing on what happens outside the company, has the flexibility of knowing how to promptly seize the opportunities that may arise

6) *Evidence-based decision making:* "Decisions based on the analysis and evaluation of data and information are more likely to produce desired results". Since the decision-making process is the result of a mental process that determines a final choice between various alternatives, it is practical evidence that some form of uncertainty is involved during a process. Hence, when making a choice, it is essential to understand the cause-effect relationships and the potential undesirable consequences. According to the standard, the objective analysis of the data ensures that there is more trust in the entire decision-making process

7) *Relationship management:* The underlying idea of this principle is that interested parties influence the performance of an organization. Relationship management can be considered as a strategy in which an organization maintains a level of ongoing engagement with its customers, suppliers and other stakeholders. This principle aims to build trust between them instead of considering the relationship as purely transactional. Establishing such a type of relationship between the parties is vital to obtain feedback that can be used to continuously improve processes and to achieve a sustained success

The quality management system requirements specified in the IATF 16949 standard, in accordance with the ISO 9001:2015 standard, prefer a process-based approach, which follows the logic of the Plan-Do-Check-Act (PDCA) cycle and risk-based thinking.

- *Risk base thinking*: "it allows the organization to identify the factors that could lead to a deviation in the planned objectives, and to put in place the necessary controls to ensure that the negative effects are minimized" (ISO 9001:2015)[8].

[8] ISO 9001:2015(en), Quality management systems — Requirements

• *PDCA Cycle*: “Management of the processes and the system as a whole can be achieved using the PDCA cycle with an overall focus on risk-based thinking aimed at taking advantage of opportunities and preventing undesirable results” (ISO 9001:2015). The PDCA cycle, as reported in the IATF 16949:2016 (in accordance to the ISO 9001:2015), can be applied to any QMS process and is a key prerequisite for continuous improvement principle. In general terms, it is an iterative, four-step technique, used for the resolution of problems and for continually improve organizational processes.

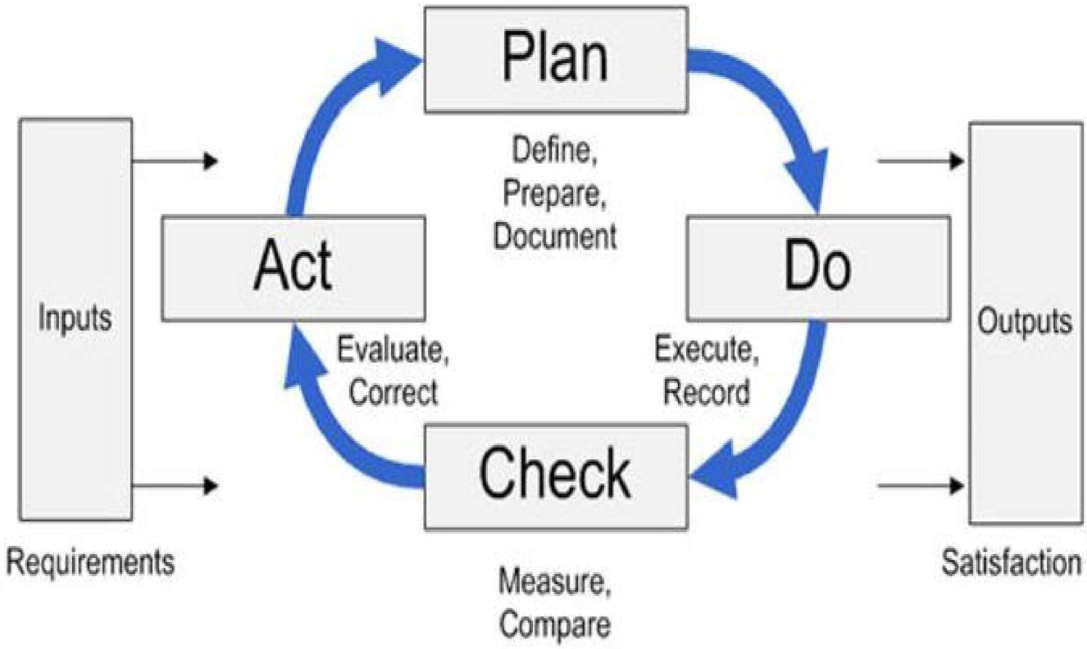

Figure 19: PDCA Cycle

As shown in Figure 19, the Deming cycle is composed of four phases and the results obtained from each of them will constitute the input for the next phase.

- PLAN: The so called “plan” phase is the first one of the cycle and it concerns the analysis of the situation under consideration (to face a problem or to exploit an opportunity), through the collection of data and information. In addition, at this stage, the objectives necessary to achieve the expected results will be decided through the implementation of an "action plan".

- DO: This is the phase where the actions necessary for the achievement of the objectives planned at the previous point are executed.
- CHECK: This further phase is about checking what has been done so far and that the actions carried out in the "Do" phase are consistent with the objectives set in the initial phase. In addition, comparisons will be made with the expected and obtained results to assess any deviations.
- ACT: The "Act" phase is the actual improvement phase. In this stage it will be decided whether to make corrective actions (when the results obtained differ from those expected) iterating the cycle, or making the process final.

2.2.2. Automotive Core Quality Tools

To build an efficient management system, IATF 16949:2016 includes some tools, known as "Quality Core Tools". Their use, as expressly required by the standard, guarantees compliance with the expected quality requirements expressed in the Company Quality Manual, so that the interested parties are fully aware that company's products and processes comply with standards. The definitions of the tools in question are provided by AIAG (Automotive Industry Action Group), a non-profit association committed to provide standards and training for automotive companies:

- *Advanced Product Quality Control and Planning Plan:* "APQP and Control Plans reduce the complexity of product quality planning for customers and suppliers by allowing customers to easily communicate their product quality planning requirements to their suppliers. Suppliers gain an understanding of basic industry requirements for achieving part approval from their customer" (AIAG-Automotive Industry Action Group)
- *Production Part Approval Process:* "PPAP is the industry standard that ensures engineering design and product specification requirements are met. Through the PPAP guideline, suppliers and customers understand the

requirements to obtain part approval of supplier manufactured parts. Applicable to all parts and commodities, application of these principles reduces delays and non-conformances during part approval" (AIAG-Automotive Industry Action Group)

- *Statistical Control of process:* "SPC is the use of statistical techniques such as control charts to analyze a process or its output so as to take appropriate actions to achieve and maintain a state of statistical control and to improve the process capability" (AIAG-Automotive Industry Action Group)
- *Failure Mode and Effects Analysis:* "FMEA is an analytical methodology used to ensure that potential problems have been considered and addressed throughout the product and process development process. Part of the evaluation and analysis is the assessment of risk. The important point is that a discussion is conducted regarding the design (product or process), review of the functions and any changes in application, and the resulting risk of potential failure" (AIAG-Automotive Industry Action Group)
- *Measurement System Analysis:* "MSA connects to measurement data that is used in nearly every manufacturing process. This guide will help the organization to assess the quality of your measurement systems, providing a basis for recognizing where improvements can be made. The result is knowledge that can be used to improve the measurement process, in turn improving repeatable product quality" (AIAG-Automotive Industry Action Group)

2.2.3. Continuous improvement and Lesson Learned definition

The continuous improvement, in addition to being one of the requirements for creating a QMS, is one of the core principles for the long-term success of a company, regardless of whether it is automotive or not. In this treaty, the concept of improvement will not be limited to the achievement of pre-established objectives; but it will refer to a constantly evolving philosophy that pushes the company to gradually improve, to achieve long-term objectives. This business philosophy can be explained through the Japanese term “Kaizen” that means “change for the better”, by using a methodical and gradual process. For implementing this methodology, it is not necessary to radically change a process; on the contrary, it is common practice either to analyze its outcomes or to make comparisons between past and current state, to identify problems and technical criticalities occurred. The starting point of this activity will be the identification of the process criticalities (for instance, using process KPI) and the discovery of their determining causes. Among the different causes identified, it will then be necessary to make a "skimming", so that the problem that has arisen is attributable to a few source causes. In conducting this type of analysis companies will refer to problem-solving tools and techniques that allow tracing the root causes and to identify possible strategies and solutions. Among the tools and techniques used in problem-solving activities to find the root-causes of a problem, the most significant are the Ishikawa Diagram (already described in the paragraph of 7Q Tools), the 5 Whys Method and 5W+1H Method.

- *5 WHYs Method*

The 5Whys method, developed in the 1930s in Japan, is a way of thinking that is based on the logical linkage of events into cause-and-effect analysis. The starting point of this method is the problem definition and, by asking “Why did this happen?”, it is possible to move to the next level. Hence, each answer to the previous question "Why?" will be the starting point of the next question. By iterating the process 5 times, both the nature of the problem and its solution gradually become clearer. This methodology can be used in conjunction with the Ishikawa diagram. In fact, once the root causes have been established (which will form the main "bones" of the fishlooking graph), it is possible to use the 5 Whys tool to search for the root causes that form the secondary "bones".

- *5W+1H Method*

Another method used in problem-solving and with a view to continuous improvement, is the 5W+1H method, that is an acronym in which every letter corresponds to a question: “What?”, “Where?”, “Who?”, “When?”, “Why?” and “How?”. The aim of this method is to examine the problem from different perspectives, in order to have an overview of the determining causes that have led to the realization of such criticality.

After collecting the root causes of the problem under consideration, the company must (following the perspective of the Deming cycle) implement corrective actions to identify the most appropriate solution to solve the problem in the short run. Once the solution has been identified, the company should focus its efforts on its implementation and ongoing monitoring. The company should then provide periodic reports where both the improvements made but also potential areas for improvement are recognized. Starting from this awareness, the concept of Lesson Learned comes out, that is to learn from the mistakes made in the past so that they do not recur in the future. “A Lesson Learned is knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. A lesson must be significant in that it has a real or assumed impact on operations; valid in that it is factually and technically correct; and applicable in that it identifies a specific design, process, or decision that reduces or eliminates the potential for failures and mishaps or reinforces a positive result.” (Secchi, P. (Ed.) (1999)[9]. From a company perspective the generation of a Lesson Learned answer the question: “How can we empower the overall system to avoid the same or similar problem in the future?”.

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[9] (Secchi P. (Ed.),1999). “Proceedings of Alerts and Lessons Learned: An Effective way to prevent failures and problems “(Technical Report WPP-167). Noordwijk, The Netherlands: ESTEC

3. Lessons Learned Management

3.1. Chapter Introduction

The aim of this chapter is to analyze the current LL Management System of Marelli EPT, spotting some windows of improvement and then presenting a new approach for collecting experience. Currently, Marelli EPT is building its Quality Management System and the Lesson Learned Management is applied only to the product development processes, by collecting LL generated by operatives. The objective of the present work is to review and to extend the existing "Bottom-up" approach for all the processes involved in the QMS, not only from a technical/practical viewpoint but also from a managerial/decision-making one. Moreover, a new approach methodology (Top-Down) will be introduced in the next paragraphs, after verifying that both models are consistent with the PDCA (in order to respect the IATF 16949:2016 key prerequisite). Then, some case studies will be processed and analyzed to assess their applicability and transversality across each QMS process.

In general, in M-EPT Lesson Learned Management is a process typically addressed in a "Bottom-up" mode to promote and to share among the QMS processes in question, what has been learned from technical issues encountered during:

- Product development
- Serial production

Hence, the LL management is typically focused only on technical aspects (independently if inside EPT Marelli or Supplier perimeter):

- Design
- Manufacturing process

For the above reasons, the LL process is normally limited to avoid repetition of problems that have already occurred. By improving the current "Bottom-up approach" and by proposing a new approach (Top-down), the candidate's objective is to extend the scope of the LL in all QMS processes also with the aim to:

• Identify not only the improvement actions introduced, to recover problems already verified, but also the derivations from the analysis of potential problems during the product life cycle and from the analysis of KPIs. Consequently, to study the most critical KPIs and those perfectly in target

• Check if the experience in question (using the appropriate KPI) is positive or negative. Consequently, by promoting to repeat the experience if the results are positive, or to try avoiding it in the future, if the results are negative.

3.2. Marelli EPT QMS process map

One of the main objectives of this chapter is to highlight the process of generating Lessons Learned and to extend it to all Quality Management System processes within the Electric Powertrain BU. As can be assessed from the introduction of the chapter, currently this methodology, still in the actual definition phase, focuses only on the product development process. In order to have an overview of the processes where the proposed methodology could be developed and applied, a fictitious process map is represented. For M-EPT corporate privacy reasons, it is not possible to disclose the map of real M-EPT QMS processes, but the candidate intends to develop a generic process map, applicable to any company in the automotive sector, including Marelli EPT. The process map (with reference to figure 20) presents three distinct macro-areas:

- Management Processes
- Customer-Focus Processes
- Support Processes

The management processes include all the activities of defining corporate objectives and the strategic choices to be implemented on which all the other processes depend. The Customer-Focus processes concern the actual operational processes, from the creation of the product to its marketing. The support processes, as the name suggests, "support" the operational processes in order to increase their efficiency and productivity.

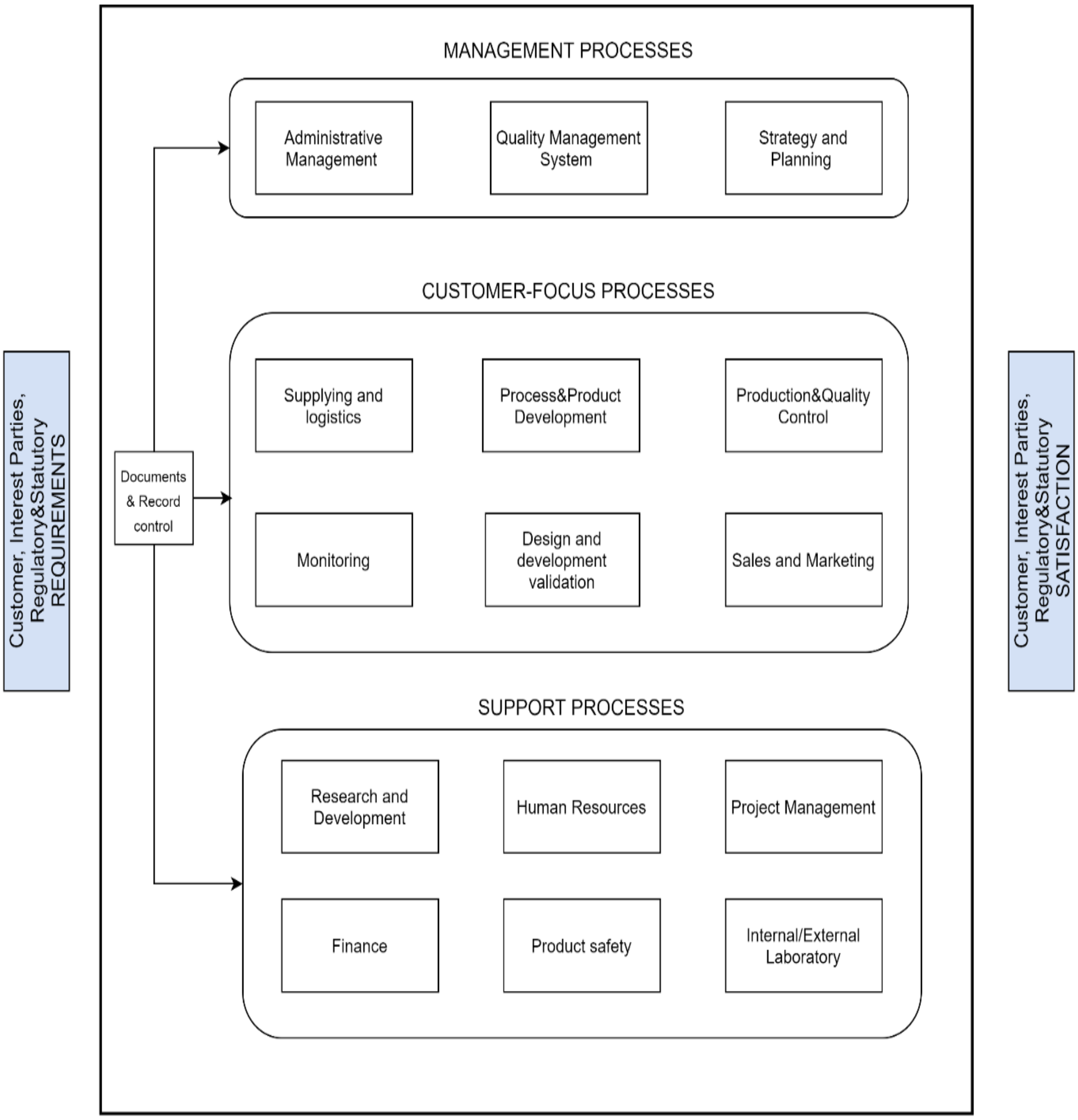

Figure 20: Fictitious Process Map

3.3. Lesson Learned Approach: Bottom-up or Top-Down?

In general, Bottom-Up and Top-down approaches are methods used for a wide range of activities, such as goal setting, budgeting and forecasting, to analyze problematic situations and build possible solutions. Top-down analysis generally refers to the use of global factors as a basis for decision making. Picturing a pyramid with the apex (top) and the base (down) placed in a horizontal position; the approach involves starting from the top and then going down. The top of the pyramid can be considered as the objective to be achieved to solve a given problematic situation; while "down" is attributable to the strategy to pursue to meet the above-mentioned goal. On the contrary, in the Bottom-up approach, the starting point of the analysis is reversed and, as the name suggests, it starts from the base of the pyramid up to the top.

In Lessons Learned Management, the Bottom-up approach results in starting the analysis from the collection of process criticalities on a day-by-day basis, through the implementation of 5W+1H Method. By contrast, the Top-Down approach sees as starting point company KPIs result analysis and potential issues analysis extracted during the whole product lifecycle. As shown in the figure below (fig. 21) for the representation of the two approaches, organizational development levels (also called "flight levels") were taken into consideration. The Flight Level model is an instrument of communication that reveals the effect of specific improvement steps at different levels:

- Operational
- Coordination
- Strategic

The first flight level (Operational) belongs to the project team which is responsible for the daily work. Team members involved are highly specialized experts, who work exclusively in a sub-area of an enormous system. At flight level 2 (Coordination), team interaction is optimized. This organizational level corresponds to the figure of the Process Owner who has the task of coordinating the work of different teams and managing the organization's processes and related output. The Level 3 is the strategic heart of the organization, where the projects and initiatives of the company converge. The strategic management is part of this flight level: the focus shift from the individual process to the overall result for the organization.

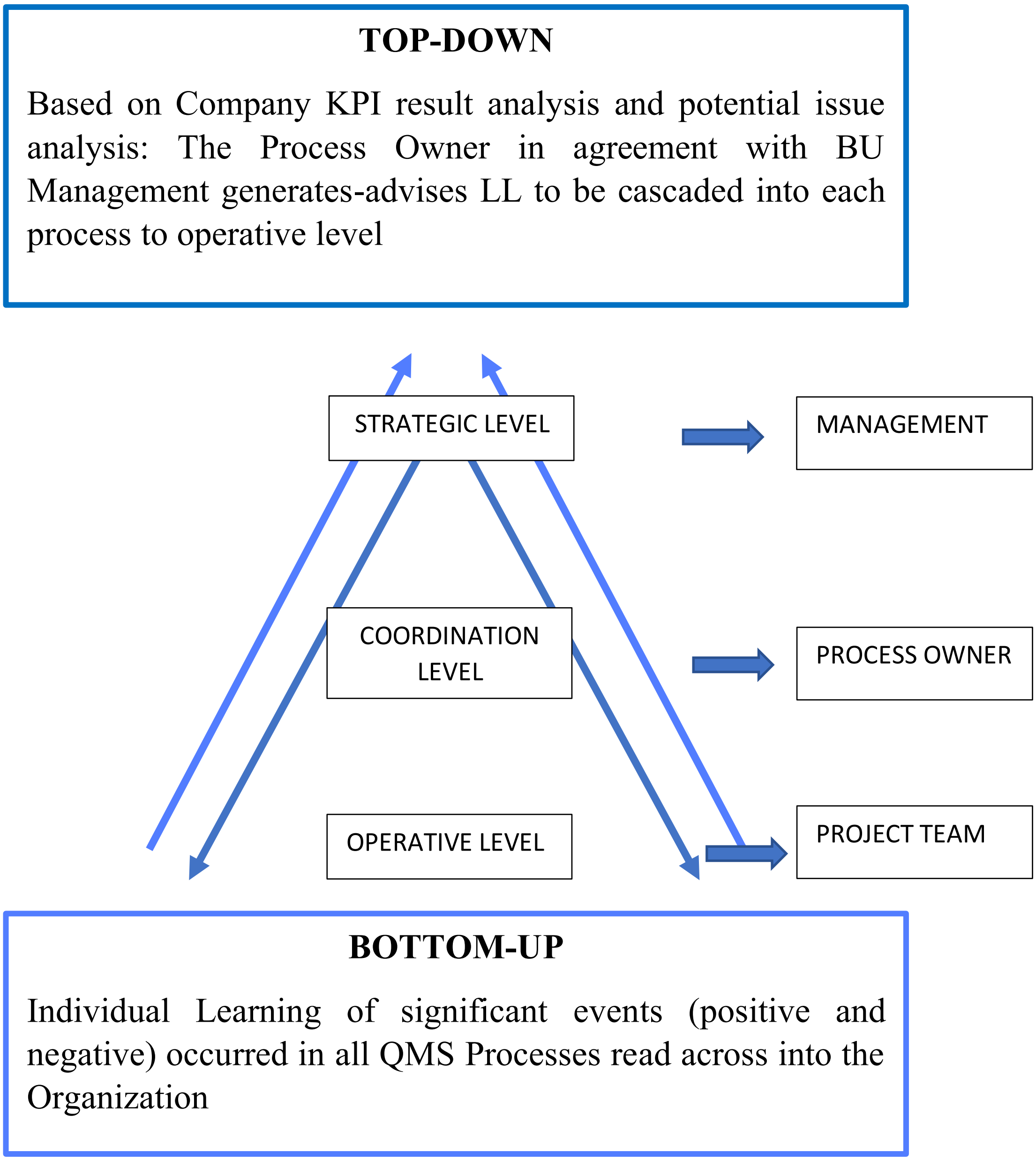

Figure 21: Bottom-up and Top-Down Approach

3.4. Lesson Learned Flow

The Lessons Learned Flow consists of a *Generation Flow*, different if approached in Bottom-up or Top-down mode, and a *Sharing Flow*, which is the same regardless of the approach used. The LL Generation process will be the main subject of this chapter, while the Sharing process will be treated exclusively from a theoretical point of view

The generation flow is divided in four main steps:

- Identify: gathering data that could be valuable for future applications
- Document & Organize: systematically documents findings
- Analyze: assess whether the collected information has the elements needed to become a Lesson Learned
- Formalize & Store: formalize the LL and archive in a shared repository

The output of the Generation process will therefore be the formalization of the LLs and the updating of the EPT database, the tool chosen by EPT to manage Lessons Learned. Consequently, the sharing process will begin with the practical use of the LLs (Operative Level) up to their dissemination among different QMS processes and EPT operational locations (Strategic Level). In general, it can be divided in three steps:

- Use & Monitor: apply the LL to current and/or new activities
- Standardize: new best practice generation
- Read across: sharing to other entities (among both QMS processes and different M-EPT sites)

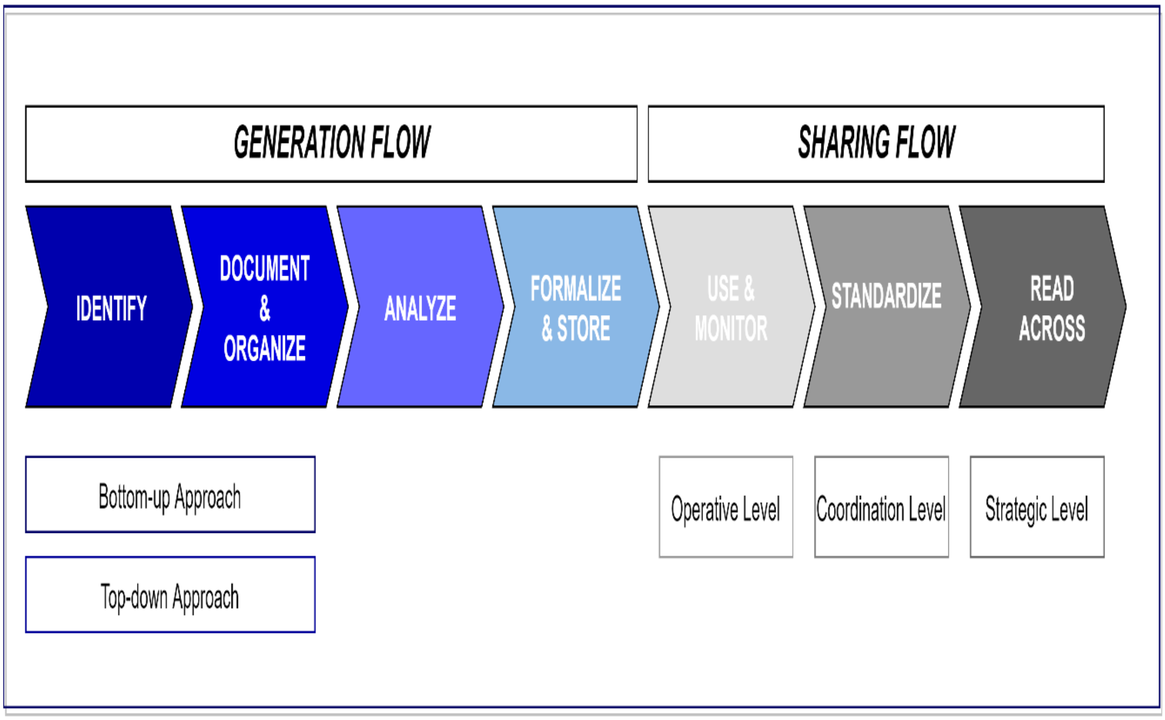

Figure 22:Lesson Learned Flow

3.5. Generation Flow

3.5.1. Bottom-up Approach

The entire LL generation process using a Bottom-up approach is explained in detail in the flowchart below (fig. 23).

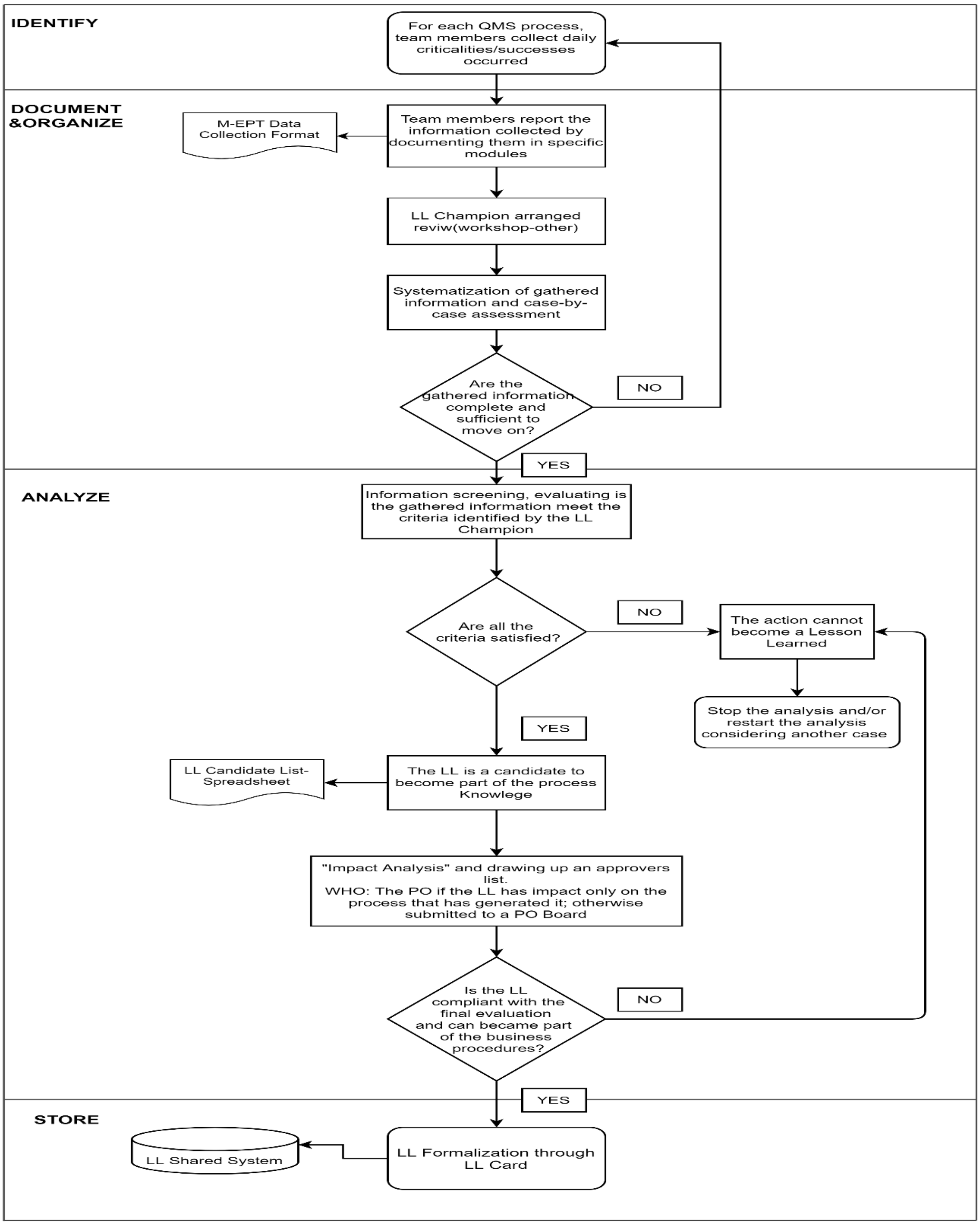

Figure 23: LL Generation Flow using a "Bottom-up" approach

The starting point of the Generation flow, approached using a Bottom-up modality, is the collection of daily criticalities/successes occurred in the phases of a given QMS process. By applying the 5W + 1H method (illustrated in the previous chapter) the team members will be able to have a global view of the criticality encountered, from different perspectives. Team members document, using a specific data collection format (figure 24) the outcomes of the 5W+1H method, also providing possible solutions and possible root causes of the criticality found in the process.

M-EPT DATA COLLECTION FORMAT

Criticality Detected Name:	

Date:		**Reference Process:**	
Product Type:		**Involved Component:**	
Customer:		**Project name:**	
M-EPT Plant/Site		Supplier:	

PROBLEM DESCRIPTION:		
WHAT?	What was observed? What is the impact? What are the possible side effects? What is the component or process under consideration? What went wrong? What are the difference wrt the normal process?	
WHERE?	Where was the problem found? Where did the problems arise? Where does it affect?	
WHO?	Who has observed the problem? Who will lead to the solution? Who does this habitually? Who is doing it right now?	
WHEN?	When did the problems arise? When was the problem encountered? When should the activity be carried out? When is it actually done?	
WHY?	Why is this a problem? Why was there a problem? Why may unwanted effects occur?	
HOW?	How was the criticality detected? How should this activity be carried out? How is it actually done? How can you take action to correct the problem?	

ROOT CAUSE DESCRIPTION	**SOLUTION PROPOSED**

LESSON LEARNED PROPOSED:	
What can be learned from the problem encountered? What are the improvement actions that do not cause the problem to reoccur? How it is possible to empower the overall system to avoid the same or similar problem in the future?	

LL Champion:		**Approver(s):**	

Figure 24: Data collection format

Figure 24 shows a possible format for data collection, where also generic questions (corresponding to the 5W + 1H method) are provided. Those questions direct the operator to document in detail the events, so that a complete picture of the situation will be available.

Thereafter, a specific figure (who will henceforth be referred to as "LL Champion"), in charge of promoting and analyzing the LLs, sets up a meeting with the team member who provided the information. LL Promoter and team members evaluate the completeness of the collected information, by systematizing them. If the LL Champion considers that the information is sufficient and it is worth investigating the criticality in question, he/she will subject it to various predefined criteria. The screening process includes several evaluation steps, such as:

1. Evaluate that the present case has not been previously investigated and has not been rejected as a possible candidate to become a LL(Checking the LL-Candidates spreadsheet)
2. Evaluate if the root causes are attributable to M-EPT Perimeter
3. Evaluate the proposed solution effectiveness
4. Evaluate the possible side effects.

After having assessed the feasibility of the results obtained in the steps illustrated above, the outcome of this activity is the definition of a LL candidate list. The latter is loaded into a specific tool (LL Candidates Spreadsheet) so that the other team members can have traces of the cases already investigated (first requirement in the criteria identified above). At this point, the Process Owner submits the possible LLs to an "Impact Analysis", carefully evaluating whether the LL has impacts even outside the process that has generated it. If so, the LL will again be subjected to analysis by a committee of Process Owners (responsible for the processes where the LL has possible effects) and a decision will be made whether to reject it or officially formalize it through the implementation of a pre-set LL Card in the shared system (EPT Lesson Learned System). The "LL Card" (see example figure 25) is a schematic and reduced version of the "data collection format" and includes the most relevant details of the new LL, such as the name, the processes and processes involved. The LL Card will be updated directly in the shared system so that team members can keep track of the new LLs introduced and refer to them when needed. The final phase of the generation of the Lessons Learned foresees the updating of the shared LL database, a special repository where all the LLs created are stored and can be easily consulted by the team of the entire BU. From this moment the "Sharing" phase begins, which will be evaluated in the next paragraphs.

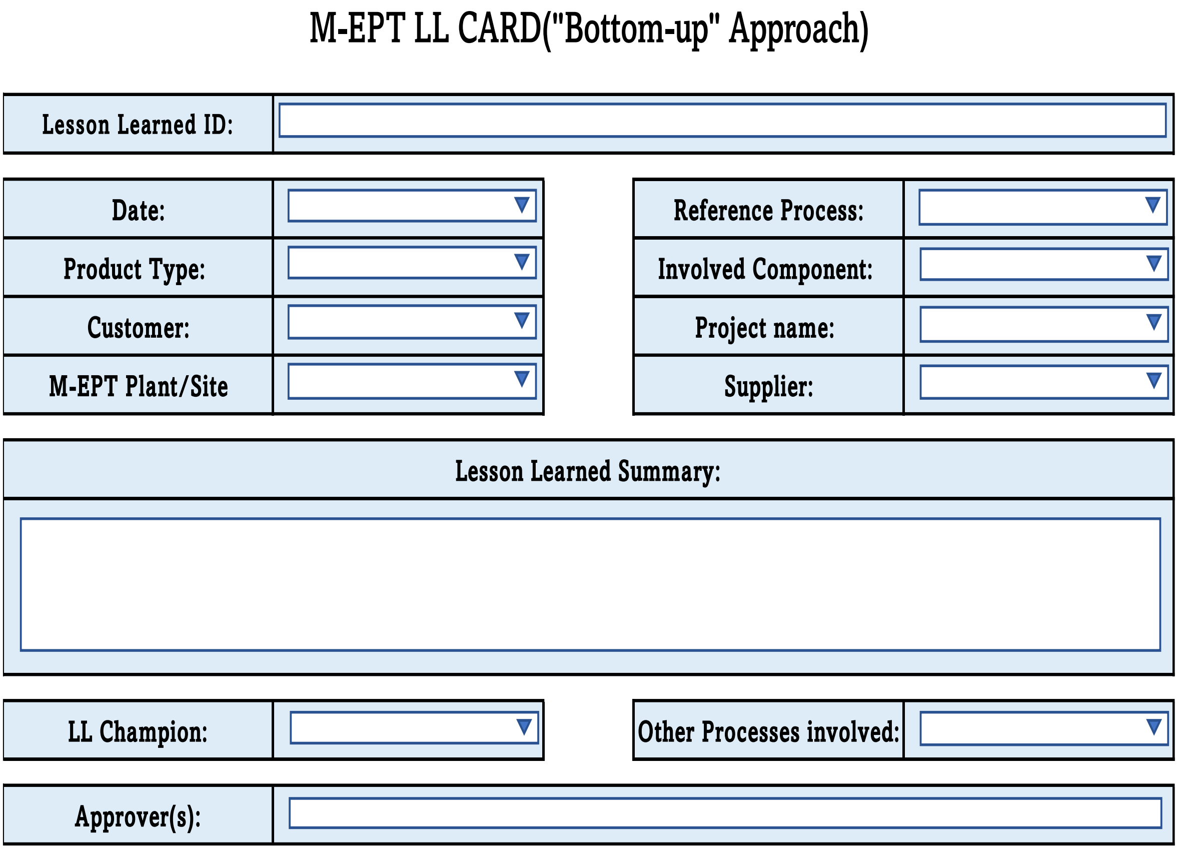

Figure 25: Lesson Learned Card using a "Bottom-up" Approach

3.5.2. Top-down Approach

The new LL generation method, based on a Top-Down approach, has its root in the KPIs analysis, taking into consideration not only the "off-target" results but also those in line with pre-established company objectives. In general, the use of Key Performance Indicators is part of the broader context of management control. In fact, KPIs are predetermined measurable values that prove how effectively a company is achieving its planned objectives. KPIs can be used not only as a performance monitoring tool, but also as a planning tool for future improvement activities. If strategic management identifies a difference between the expected objective and the result achieved, it can take the necessary measures to correct this deviation. The LL Generation flow refers to figure 27, where the flowchart of this activity is represented in detail. As it can be easily seen from the flowchart, the main difference in the two proposed approaches lies in the initial inputs and in the identification and documentation phases.

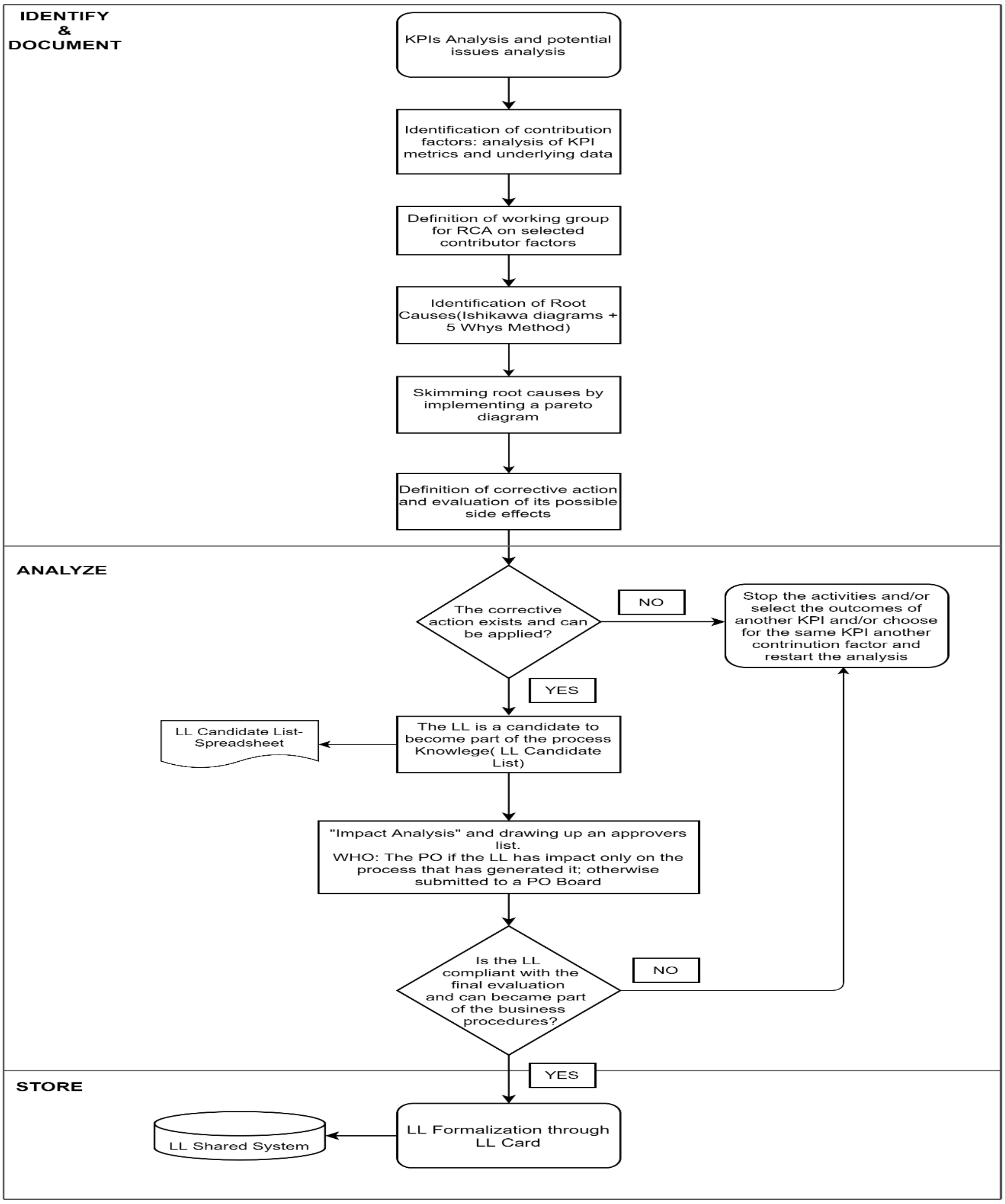

Figure 27: LL Generation Flow using a "Top-down" approach

The process begins with the determination of a specific Key Performance Indicator and the identification of the contributing factors that triggered the performance in question. This activity is carried out by the LL Champion who, thanks to the use of the qualitative tools available, first identifies the contribution factor that requires a priority intervention. Then, he/she will analyze the root causes that determined the present phenomenon. Root cause analysis will be implemented using Ishikawa diagrams and the 5Whys method. Once the root causes have been identified, the LL Promoter identifies the existence and applicability of both corrective actions and possible side effects. At this point, by evaluating the content, if the LL Champion assesses that corrective actions cannot be applied or do not exist, the LL Generation flow follows one of the three options listed:

1) The analysis stops without producing any LL
2) The analysis restarts by identifying another contributor factor
3) The analysis restarts by identifying the results of a new KPI

On the contrary, if the LL Champion identifies the existence and therefore the applicability of the corrective actions. The process goes on and the LL Champion, by arranging all the information collected, introduces a list of possible LL candidates. From this moment on, the generation flow follows the process phases identified in the Bottom-up approach. The LL candidates will be subject to an "Impact analysis" to evaluate whether each possible Lesson Learned has impact even outside the process that has generated it. Even in the Top-Down approach, the LL will be evaluated by a Board of Process Owners if there are significant impacts on other QMS processes. If the LL passes the evaluation of the process owners, it follows the final step of the generation, i.e. its formalization through the implementation of a LL Card and its updating on the shared database. Differently from the approach described above, in the new proposed methodology, the LL Card will report details relating to the KPI under analysis. In addition, it will also contain references to the root causes detected, the possible side effects and the involved components (see figure 28).

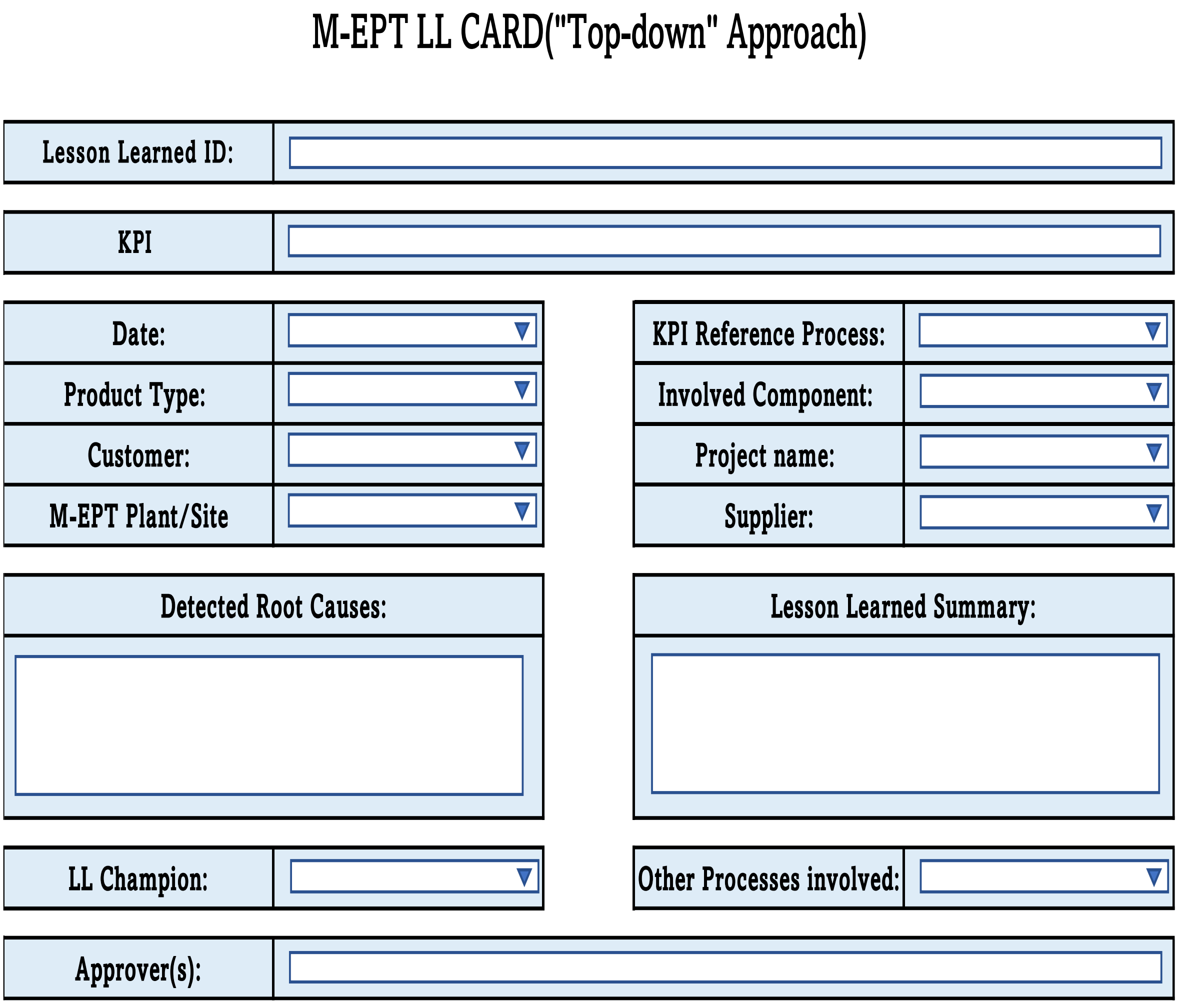

Figure 28: Lesson Learned Card using a "Top-Down" Approach

Purely as an explanation of the proposed "Top-Down" methodology, the candidate proposes a generic fictitious example, not attributable to M-EPT. Following the main steps illustrated in the flowchart represented in figure 27, the goal is to obtain possible LLs starting from the identification of a generic KPI considered out of target.

➢ *Identification of the KPI under analysis*

To implement the above-illustrated Top-Down approach, the candidate intends to use the "Scrap Rate" as a generic KPI. The scrap rate is a process indicator that measures the quality of the production outcome. An "out of target" value of this indicator could be attributable to poor raw materials, negligent application of production procedures, defective machinery, or inexperienced operators, which will result in an increase in costs for the company and in a consequent daily slowdown of operations. Furthermore, another consequence of having a high scrap rate could be the inability to produce enough finished products to fulfill customer orders. Consequently, a high and uncontrolled value of the KPI in question could also have an impact on other QMS processes; such as the procurement process or the inbound and outbound logistics process. In general, the scrap rate can be calculated and evaluated as:

$$Scrap\ rate = \left(\frac{Number\ of\ units\ scrapped}{Total\ Number\ of\ units\ produced}\right) * 100$$

➢ *Identification of Root Causes*

To investigate the root causes that led to an anomalous value of the reject rate, an Ishikawa diagram is implemented with generic causes attributable to the unexpected high value of the KPI under examination. The main contributing factors and possible causes, obtained by iterating the 5Whys Method, are listed below:

- *Manpower*: low experience, lack of awareness in control plan application, lack of training, lack of internal communication
- *Machines*: old-fashioned equipment, faulty machinery
- *Methods*: incorrect application of process procedures, rework procedure not available from customer, incorrect maintenance procedures, timing of implementation of design changes
- *Materials*: poor raw quality material, lack of material available
- *Measurements*: incorrect prediction of internal scrap rate, poor control of incoming material

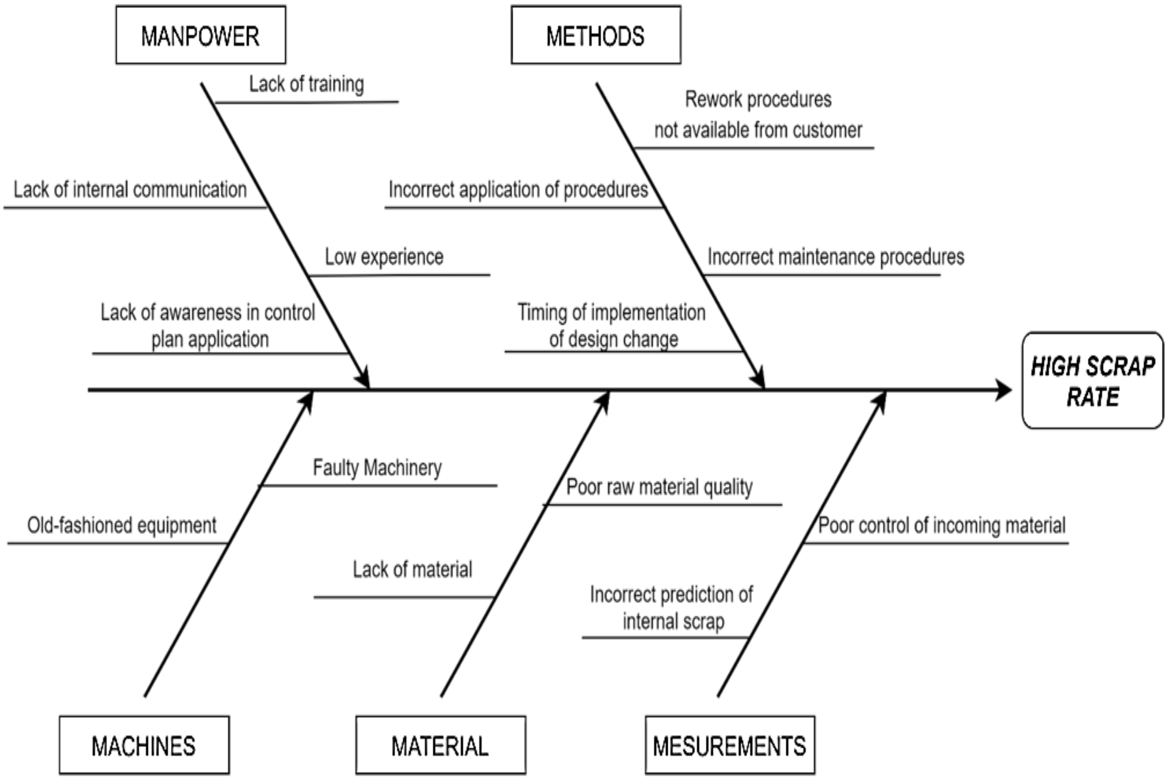

Figure 30: Ishikawa diagram

➢ *Root Causes Skimming*

Once the possible causes have been identified, the candidate carries out a Pareto analysis (purely explanatory of the methodology) on the afore-mentioned causes. The aim of this step is to highlight which could be the main root causes attributable to the undesirable negative effect, that require immediate corrective actions. Through the Pareto graph, it is possible to have visual evidence of the source causes that have the greatest impact on the event in question. As shown in the diagram (see fig. 31), the key causes attributable to a high scrap rate are:

- Inefficient machinery
- Rework procedure not yet agreed with the customer
- Lack of internal communication
- Incorrect application of procedures
- Lack of training

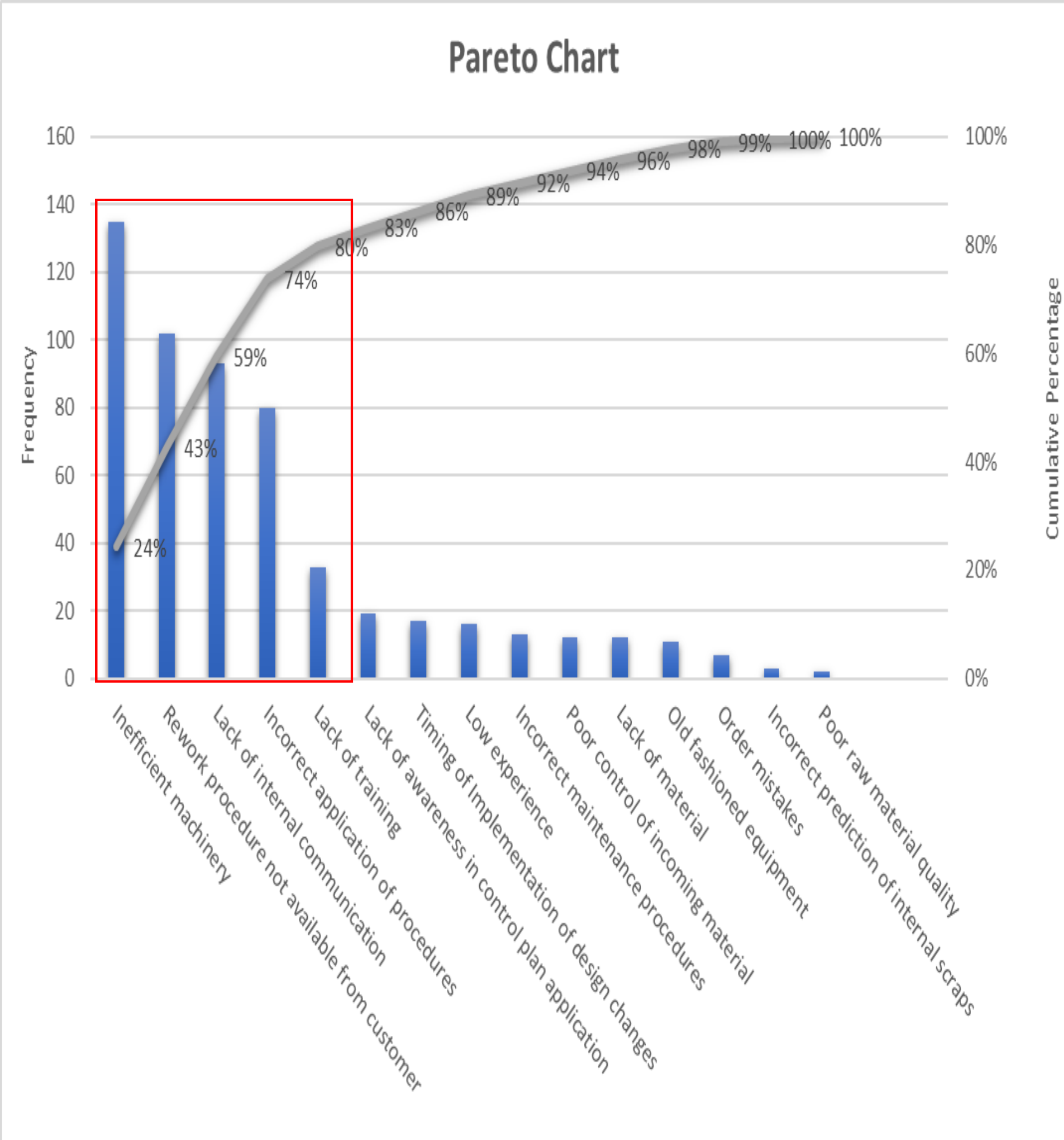

Figure 31: Pareto Chart

Therefore, by applying the Pareto principle, the candidate focus exclusively on the most impacting elements. Hence, it is possible to identify possible corrective actions that could be implemented to solve the above-mentioned causes in the short-run. Next, the candidate brainstorms to uncover possible side effects that could arise if root causes are not corrected. Starting from the gathered information, the introduction of some possible LL comes out, which will form the "LL Candidate List".

➢ *Definition of possible corrective actions*

- Verify that team members are aware of both procedures to be applied and the application of control plans, through checks carried out before the production launch
- Study the flow of the production process and evaluate which are the critical points where the need to carry out rework may arise
- Review the entire management of the procedures and check if there are gaps within the management system of the changes introduced by the customer
- Improve the efficiency of machinery through continuous monitoring of the OEE (Overall Equipment Effectiveness), minimizing the "Equipment-effectiveness loss"

➢ *Brainstorming to identify the possible side effects*

- Inability to produce enough finished products to fulfill the customer order
- Need to increase procurement volumes without precise estimates
- Delayed deliveries of customer orders
- Increase in costs for the company
- Slowdown in operations
- Urgency to introduce process changes without waiting for customer approval
- Customer dissatisfaction

➢ ***Proposed Lessons Learned***

Modify project schedule activities in order to:

- Anticipate operator training and provide operators with checklist to trace all operation performed during previous productions
- Anticipate discussion with customer for agreement on rework activities and procedures.

The proposed LLs will then be analyzed by both the reference PO and LL Champion, who will evaluate the LL content by subjecting them to an impact analysis; so that the possible other processes involved can be taken into consideration. Once the LL has passed the final evaluation step, a LL Card will be created showing all the peculiar aspects investigated, which will be shared with all the members of the process team.

3.5.3. Generation Flow compliance with PDCA

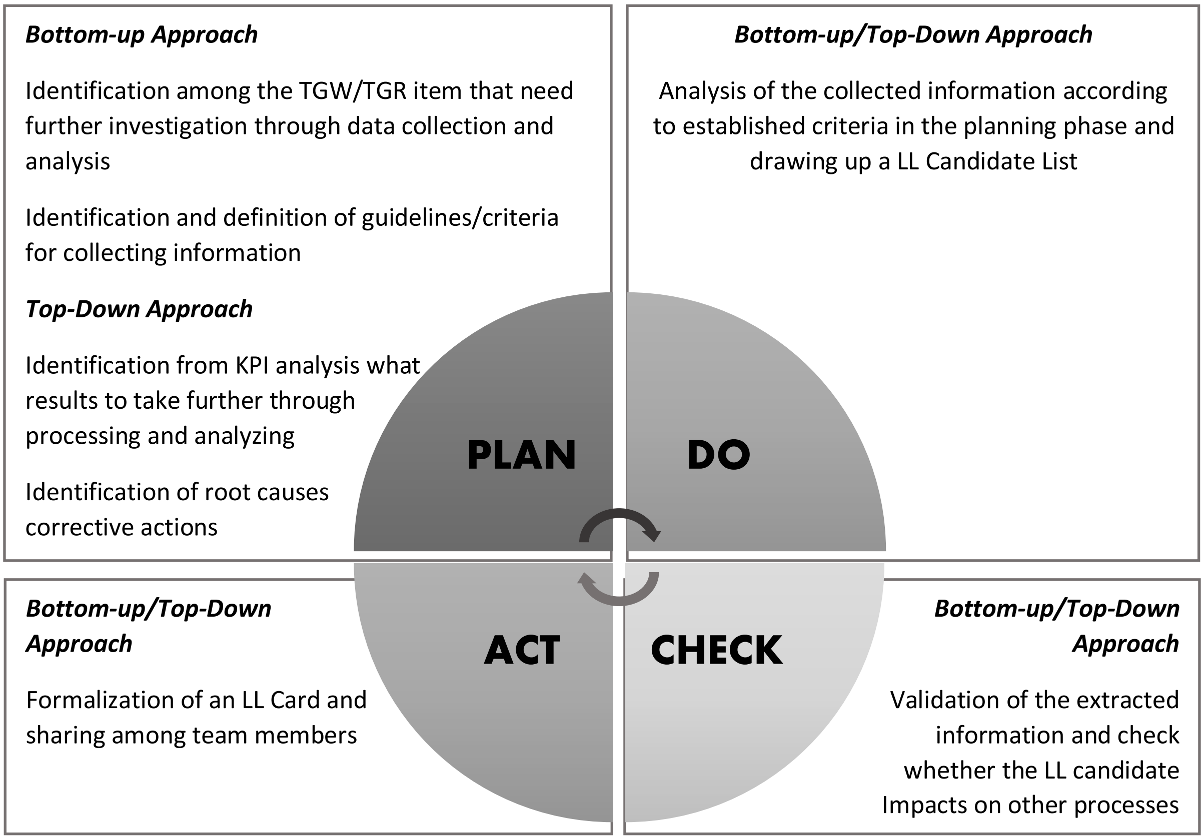

Figure 32: Generation Flow compliance with PDCA

3.6. Sharing Flow

The Lessons Learned Sharing Flow, as described in the opening paragraph, is the same for both proposed methodologies and is divided into three well-defined steps (see fig. 33) described in the flowchart :

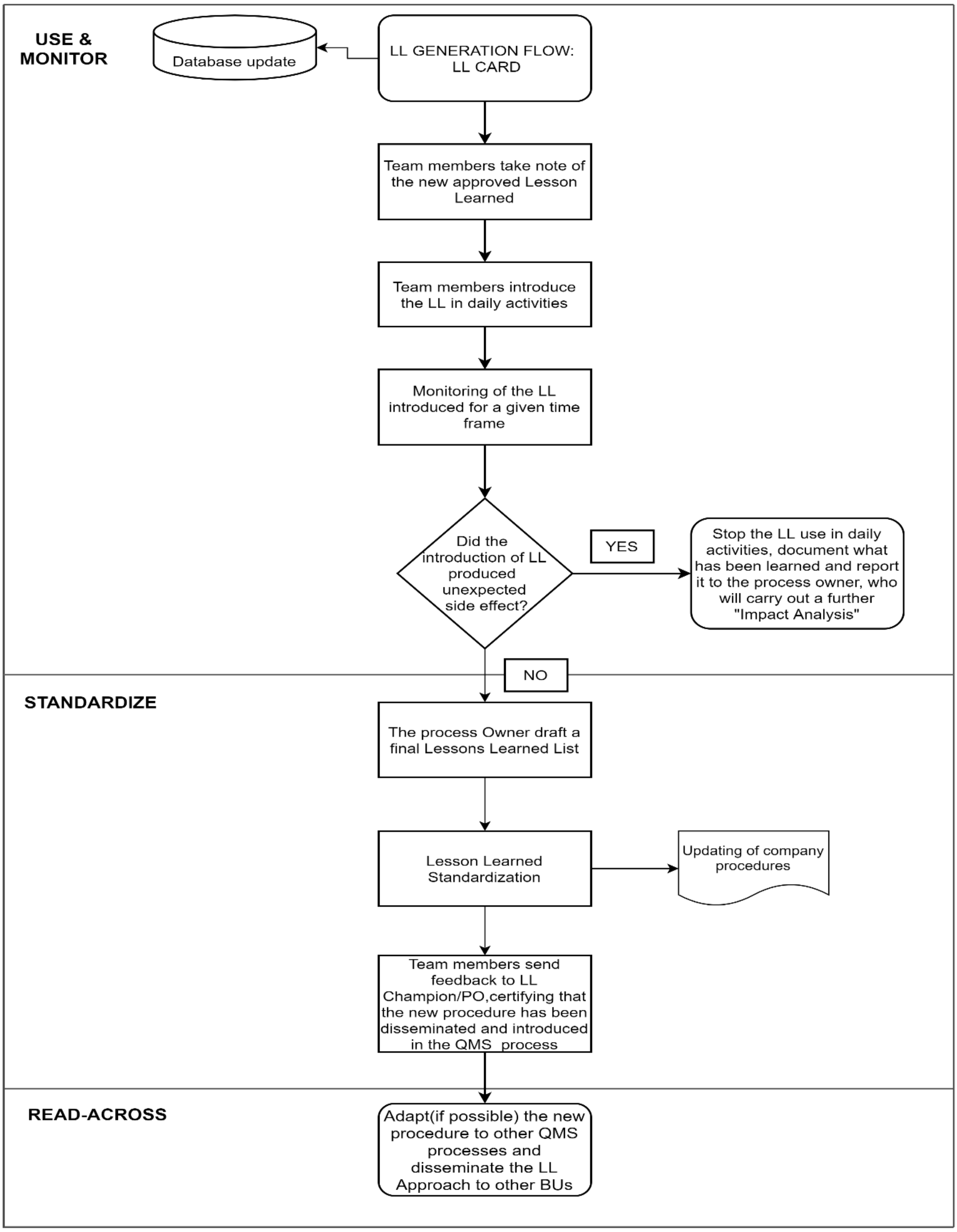

Figure 33: Lesson Learned Sharing Flow

1) USE & MONITOR

The Sharing flow has as input the LL generation process and the LL theoretical formalization. In fact, once the Process Owner (or the committee of Process Owners) has approved the proposed Lesson Learned, the team members become aware of the new approved LLs card by consulting the shared system. At this moment the first phase of the sharing process, the so-called "USE & MONITOR", begins. Team members introduce LLs into their daily activities and monitor their effectiveness from an applicative viewpoint. The monitoring activity continues for a given period decided either by the LL Champion or by the Process Owner. This activity could be carried out with the aid of tools, such as control charts, to verify that there are no anomalous values due to special causes not taken into consideration during the LL Generation Flow. Operators report on a specific form any side effect due to the introduction of the LL. Once the predetermined monitoring period has ended, if the LL has not caused unexpected side effects neither on the process that has generated it, nor on other QMS processes, the first phase ends. The Sharing process is ready to enter the next phase.

2) STANDARDIZE

The standardization phase provides as a first step the drafting of a LLs list that produced positive results in the preceding phase. At this point, the LL is ready to be standardized within the process that generated it and it can officially become part of company procedures/guidelines. A further monitoring period (of variable duration) of the new standard will follow, in which the members of the process will have to send feedback to the process owner or the LL Champion, certifying that the new procedure introduced has been disseminated and it is being applied within the process.

3) READ ACROSS

The last phase of the Sharing Flow is that of disseminating both the standards introduced among the various QMS processes and the methodology among the different BU sites. The process of dissemination among the QMS processes involves "taking note" of improvements made to the process that generated the initial LL and to adapt the LL (if possible) to other processes. The process of sharing the methodology among BU sites provides for the aid of "awareness programs", so that other M-EPT plants can also be aware of the improvements made by the proposed methodology.

3.6.1. Sharing Flow compliance with PDCA Cycle

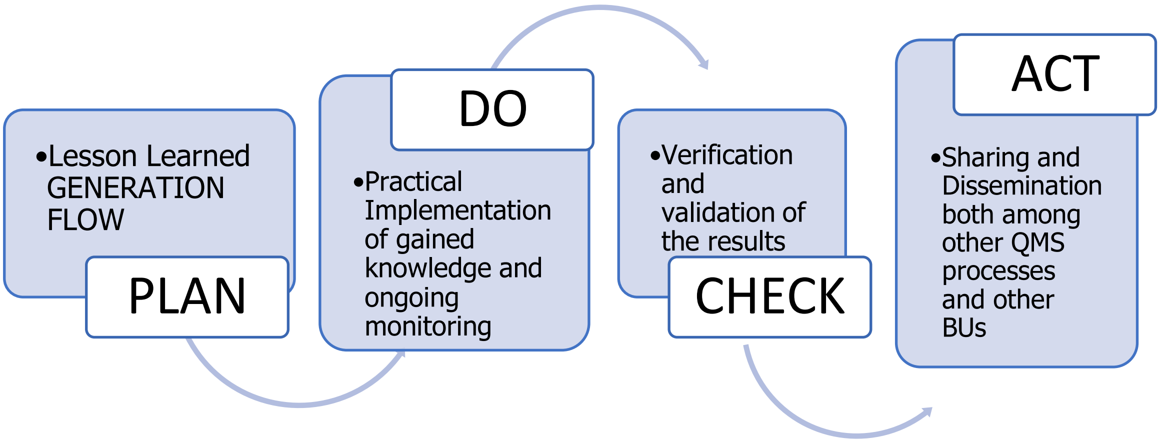

Figure 34: Sharing Flow Compliance with PDCA

4. Practical Implementation: Case Studies

To have practical evidence of the extended methodology, proposed in the previous chapter, the candidate develops two case studies related to actual problems occurred in M-EPT. The candidate's objective in this phase is to shift the focus from the Lessons Learned of a technical nature to those of managerial one, that could become part of the company know-how. Both cases analyzed do not fall within the processes for which the implementation of an LL is currently envisaged. Consequently, the candidate (interfacing with area managers) was charged to reconstruct the dynamics that determined the occurrence of the critical issues in question. For both cases under examination, the candidate illustrates an initial overview of the criticality encountered and identifies the Possible LLs through the implementation of the “Bottom-up” approach. For reasons of corporate privacy, it is not possible to provide sensitive corporate data (such as the names of suppliers or customers).

4.1. CASE 1: Safety goal violation

Foreword

ISO 26262 is an international standard for the functional safety of automotive vehicles equipped with electrical systems. The standard defines some requirements to be met to ensure the adequacy of the entire system, including tools, methods and processes used to develop it. Among the standard requirement, "Safety goals" are key requirements leading to the system development, in compliance with functional safety; moreover, they define the reaction of the system when a safety problem occurs. One of the safety goals for inverter-type components provides that the inverter sets a torque value that is always controlled to the connected electric motor, to ensure that the motor operates in known conditions. If a generic error condition occurs, whereby the inverter is no longer able to control the torque, the system (in accordance with the criteria imposed by functional safety) implements a "fail safe reaction". In this specific case, the inverter would set the motor to zero torque, placing both the vehicle and the driver in a completely safe condition.

Problem occurred

The case study under consideration refers to the first inverter project of M-EPT. In the process involved, product development was responsible for the design of the software, hardware and that of the entire system. Furthermore, M-EPT was also responsible for the validation of the system (activity conducted through tests). The non-formalized agreement with the customer foresaw that the latter would have provided vehicles to allow the installation of the device (under development) to carry out the related validation; thus, verifying that the entire system behaved consistently with the safety goals defined by the functional safety standard. The customer did not provide the vehicles to carry out the tests and consequently, M-EPT did not carry out the validation of the envisaged system. M-EPT, after a given period, performed a containment action by proposing to the customer to send a set of test-cases. Hence, the customer would have been able to carry out the validation test directly on its own vehicles. The customer, after having performed them, detected the presence of a violation of a safety goal: in certain operating situations and in the presence of other causes, there was the risk of implementing an uncontrolled torque. The gathered information is collected in the data collection format below (see fig. 35).

M-EPT DATA COLLECTION FORMAT

Criticality Detected Name:	SAFETY GOAL VIOLATION LATELY FILTERED

Date:	01/08/2021	**Reference Process:**	FUNCTIONAL SAFETY
Product Type:	INVERTER	**Involved Component:**	INVERTER
Customer:	OEM	**Project name:**	X
M-EPT Plant/Site	N/A	**Supplier:**	N/A

PROBLEM DESCRIPTION:		
WHAT?	What was observed? What is the impact? What are the possible side effects? What is the component or process under consideration? What went wrong? What are the difference wrt the normal process?	IN A SMALL RANGE OF THE REQUIRED TORQUE FIELD, IN THE EVENT OF A SOFTWARE MALFUNCTION, THE IMPLEMENTED TORQUE IS NOT MONITORED BY THE SAFETY SOFTWARE. POTENTIALLY WORKABLE AN UNCHECKED TORQUE
WHERE?	Where was the problem found? Where did the problems arise? Where does it affect?	BY SYSTEM TESTS MADE DURING PRODUCT DEVELOPMENT ON THE CUSTOMER VEHICLE
WHO?	Who has observed the problem? Who will lead to the solution? Who does this habitually? Who is doing it right now?	CLIENT VALIDATION ENGINEER AND M-EPT APPLICATION SYSTEM ENGINEER
WHEN?	When did the problems arise? When was the problem encountered? When should the activity be carried out? When is it actually done?	FINAL VALIDATION CAMPAIGN ASSOCIATED TO A CARRY OVER PRODUCT
WHY?	Why is this a problem? Why was there a problem? Why may unwanted effects occur?	UNCHECKED TORQUE - DANGEROUS VEHICLE SITUATION BOTH FOR THE DRIVER AND FOR OTHER VEHICLES / PEDESTRIANS
HOW?	How was the criticality detected? How should this activity be carried out? How is it actually done? How can you take action to correct the problem?	CASE TEST PERFORMED ON VEHICLE BY THE CUSTOMER, BASED ON M-EPT REQUEST

ROOT CAUSE DESCRIPTION	**SOLUTION PROPOSED**
TECHNICAL : SET OF CALIBRATIONS NOT SUFFICIENTLY ACCURATE TO GUARANTEE TORQUE MONITORING OVER THE WHOLE TORQUE RANGE REQUIRED; ***SYSTEMIC*** : TURNOVER OF THE KEY TECHNICAL FIGURES ASSOCIATED WITH FAILURE TO FORMALIZE THE AGREEMENTS WITH THE CUSTOMER	***TECHNICAL*** : MODIFICATION OF THE CALIBRATION SET

LESSON LEARNED PROPOSED:	
What can be learned from the problem encountered? What are the improvement actions that do not cause the problem to reoccur? How it is possible to empower the overall system to avoid the same or similar problem in the future?	***SYSTEMIC LL*** : 1)ASSOCIATE ANNEX TO CUSTOMER DOCUENTS FOR FORMALIZATION OF AGREEMENTS (FOR THE MOST DELICATE ASPECTS); 2)IMPROVE SAFETY CULTURE; 3)HAVE A STRUCTURED AND UNIFIED PROCESS FOR THE TURNOVER OF KEY FIGURES

LL Champion:	N/A	**Approver(s):**	N/A

Figure 35: Case 1 "Safety Goal Violation" data collection

Root Causes

Once the problem was discovered, M-EPT carried out a long and detailed analysis to discover the causes that led to the above-explained negative experience. The root cause, although of a technical nature, was closely linked to other causes of systemic nature. The technical-root cause (not covered by the present case) concerned a calibration, that did not cover all possible conditions of use. On the contrary, the root cause of a management type, on which the candidate has focused, can be traced back to:

1) frequency of turnover of the personnel employed on the project

2) incorrect communication on the status of the system tests

3) lack of formalization agreements with the customer, whose content was therefore not easily available from the resources taking over the activity

Proposed Lessons Learned

1) Setting up a structured handover
2) Improve Safety Culture
3) Associate annex to customer documents for formalizing agreements
4) Have a structured and unified process for the turnover of key technical figures

Once the LL Candidate List have been subjected to an impact analysis by the LL Champion, the LL card can be loaded into the shared system. The figure below (fig. 36) shows a possible example of the generation of an LL Card concerning one of the LL proposed.

M-EPT LL CARD

Lesson Learned ID:	IDENTIFICATION OF A STRUCTURED PROCESS FOR THE TURNOVER OF KEY FIGURE

Date:	1/11/2021	**Reference Process:**	FUNCTIONAL SAFETY
Product Type:	INVERTER	**Involved Component:**	INVERTER
Customer:	OEM	**Project name:**	N/A
M-EPT Plant/Site	N/A	**Supplier:**	N/A

Lesson Learned Summary:
THE COMPONENT IN QUESTION IS THE INVERTER. THE PROBLEM INVESTIGATED CONCERNS THAT IN A REDUCED RANGE OF THE TORQUE FIELD REQUIRED, IN THE EVENT OF A MALFUNCTION OF THE SOFTWARE, THE IMPLEMENTED TORQUE IS NOT MONITORED BY THE SAFETY SOFTWARE. POSSIBLE SAFETY PROBLEMS FOR THE DRIVER AND THE VEHICLE ITSELF. THE ROOT CAUSE OF A SYSTEMIC NATURE IS THE LACK OF A STRUCTURED AND UNIQUE PROCESS FOR THE TURNOVER OF TECHNICAL FIGURES ASSOCIATED WITH FAILURE TO FORMALIZE THE AGREEMENTS WITH THE CUSTOMER.

LL Champion:	N/A	**Other Processes involved:**	X

Approver(s):	N/A

Figure 36: Case 1 example of LL Card

4.2. CASE 2: Introduction of modifications prior to completion of customer approval flow

Foreword

By “product modification” is meant a change of one or more elements either of a drawing or a technical document concerning the product; without altering its nature. The change can concern components’ shape, dimensions and materials. While, by “process modification” is meant a change in the production process not deriving from product modifications. In general, when a change in both product and process is introduced, the latter must respond to a defined flow before being launched on the production line: The customer is informed through an initial PPAP→ The customer approves the proposed change → Eventual validation / test of the modification → New PPAP sampling → Final customer approval→ Mass production

Furthermore, when a change is introduced on a component by the supplier to Marelli, the goods delivered must include the updating of the Part Number, so that the system used in incoming logistics can recognize that the goods delivered has been subject to change. In general, the serial number of the product have an alphanumeric code + version and revision. The version is updated every time minor changes are made, that is, when they do not impact on functionality, reliability and costs. On the contrary, the modification of the revision takes place when the changes have a significant impact on the product and / or process. Moreover, it also implies the update of the parent serial number from which the component comes from.

Overview

M-EPT requires the stator copper coil supplier to increase the volumes supplied, because the percentage of waste on the stator line was very high (approximately 70%). The supplier introduces a first modification, approved through a PPAP by M-EPT, according to which the production of the aforementioned component would have taken place on a production line different from the one used and validated by agreements. M-EPT, before introducing the component subject to modification in the production line, should have informed the customer through a specific PPAP. Since there was no modification of the part number of the incoming "new" material supplied, the system was not able to identify that the material in question was different from the one previously ordered. Consequently, no specific checks were carried out on the incoming side and the copper wire produced by the new line entered the M-EPT production process with the same part number as the first batch requested to the supplier. The material without PPAP approved by the final customer was then used in the production line.

M-EPT DATA COLLECTION FORMAT

Criticality Detected Name:	INTRODUCTION OF MODIFICATIONS NOT AUTHORIZED BY CUSTOMER

Date:	29/05/2019	**Reference Process:**	PRODUCTION
Product Type:	STATOR	**Involved Component:**	COPPER COIL
Customer:	OEM	**Project name:**	X
M-EPT Plant/Site	BARI	**Process Owner:**	N/A

PROBLEM DESCRIPTION:		
WHAT?	What was observed? What is the impact? What are the possible side effects? What is the component or process under consideration? What went wrong? What are the difference wrt the normal process?	A MODIFICATION NOT PREVIOUSLY APPROVED BY THE CUSTOMER WAS INTRODUCED ON THE PRODUCTION LINE. THE COMPONENT IN QUESTION IS THE COPPER COIL OF THE STATOR AND THE CHANGE CONCERNS ITS PRODUCTION ON A NEW PRODUCTION LINE
WHERE?	Where was the problem found? Where did the problems arise? Where does it affect?	THE CRITICALITY WAS FOUND ON THE STATOR LINE
WHO?	Who has observed the problem? Who will lead to the solution? Who does this habitually? Who is doing it right now?	MEMBERS OF THE PRODUCTION TEAM AND PROCESS OWNER
WHEN?	When did the problems arise? When was the problem encountered? When should the activity be carried out? When is it actually done?	THE MODIFICATION WAS INTRODUCED IN NOVEMBER 2019
WHY?	Why is this a problem? Why was there a problem? Why may unwanted effects occur?	THE NEW COMPONENT, ON WHICH THE MODIFICATION HAS BEEN MADE BY THE SUPPLIER (APPROVED BY M-EPT) ENTERS THE PRODUCTION PROCESS WITH THE SAME PART NUMBER AS THE FIRST BATCH REQUIRED FROM THE SUPPLIER,BOTH WITHOUT INCOMING CONTROLS AND FINAL CUSTOMER APPROVAL
HOW?	How was the criticality detected? How should this activity be carried out? How is it actually done? How can you take action to correct the problem?	THE ACTIVITY SHOULD HAVE BEEN CARRIED OUT WHILE WAITING FOR THE CUSTOMER'S APPROVAL TO LAUNCH ON THE PRODUCT LINE THE COMPONENT SUBJECT TO CHANGE.

ROOT CAUSE DESCRIPTION	**SOLUTION PROPOSED**
LACK OF A PROCEDURE THAT TAKES INTO ACCOUNT THE MODIFICATIONS THAT DO NOT REQUIRE THE UPDATING OF THE PART NUMBER	

LESSON LEARNED PROPOSED:	
What can be learned from the problem encountered? What are the improvement actions that do not cause the problem to reoccur? How it is possible to empower the overall system to avoid the same or similar problem in the future?	1)DELIVER THE INBOUND CHANGED GOODS WITH SEPARATE DOCUMENTS AND DIVIDE THE GOODS A SPECIFIC WAY 2) INTRODUCTION OF A TEMPORARY PART NUMBER USED TO KEEP TRACK OF GOODS SUBJECT TO CHANGE, UNTIL THE CUSTOMER APPROVAL PROCESS IS COMPLETE

LL Champion:	N/A	**Approver(s):**	N/A

Figure 37:CASE 2 "Introduction of modifications not authorized by customer" data collection

Root Causes

The problem arises when there are changes that do not involve updating the part number. In the case in question, it was correct that both the revision and the version of the serial number should have not been changed, since the copper wire was the same, but simply produced on another production line. Consequently, the root cause can be traced back to the lack of a procedure that also considers the modifications that do not require the updating of the part number.

Proposed Lessons Learned

When there is a component subject to change which does not require the updating of its part number:

1) The purchasing process asks the suppliers to deliver the goods subject to modification with separate transport documents. This would allow the logistics to separate the incoming goods in a specific way. In addition, logistics could introduce a block in the company ERP system for which the need to carry out an acceptance check is associated with those goods delivered
2) A temporary part number could be used so that the system (at the time of introduction of the change) not recognizing the part number, would report it. Consequently, when goods were delivered with the temporary part number, specific checks would be carried out. Once the goods have been checked and the changes have been formalized and approved by the customer, the goods can enter the production line. The temporary part number will then be used until the customer approval process is complete and then the initial formal part number would continue to be used.

The figure below (fig. 38) shows a possible example of a LL Card concerning the second LL proposed, by assuming that the proposed LL has been subjected to accurate analysis with positive results and can be introduced into the shared system.

M-EPT LL CARD

Lesson Learned ID:	INTRODUCTION OF A TEMPORARY PART NUMBER ON COMPONENTS SUBJECT TO CHANGE, WHEN UPDATING OF THE ORIGINAL PART NUMBER IS NOT REQUIRED

Date:	1/11/2021	**Reference Process:**	PRODUCTION
Product Type:	STATOR	**Involved Component:**	COPPER COIL
Customer:	OEM	**Project name:**	N/A
M-EPT Plant/Site	N/A	**Supplier:**	N/A

Lesson Learned Summary:
A MODIFICATION ON THE COPPER COIL OF THE STATOR NOT PREVIOUSLY APPROVED BY THE CUSTOMER WAS INTRODUCED ON THE PRODUCTION LINE. THE MODIFIED COMPONENT ENTERS THE PRODUCTION PROCESS WITH THE SAME PART NUMBER AS THE FIRST BATCH REQUIRED FROM THE SUPPLIER, BOTH WITHOUT INCOMING CONTROLS AND FINAL CUSTOMER APPROVAL. THE ROOT CAUSE CAN BE TRACKED TO THE LACK OF A PROCEDURE THAT TAKES INTO ACCOUNT THE MODIFICATIONS THAT DO NOT REQUIRE THE UPDATING OF THE PART NUMBER. THE LL CONCERNS THE INTRODUCTION OF A TEMPORARY PART NUMBER USED TO KEEP TRACK OF GOODS SUBJECT TO CHANGE, UNTIL THE CUSTOMER APPROVAL PROCESS IS COMPLETE

LL Champion:	N/A	**Other Processes involved:**	SUPPLYING/LOGISTICS

Approver(s):	N/A

Figure 38: Case 2 LL Card example

5. Conclusion

Summarizing the practical evidence brought out by the implementation of the case studies showing the extension of the "Bottom-up" methodology proposed for the creation of LL, it is possible to conclude that this approach is adaptable and usable for all QMS processes. In fact, both case studies analyzed are not directly linked either to the product development or to the mass production process, for which the LL in M-EPT is currently envisaged. By analyzing and reconstructing the critical issues encountered, it is therefore possible to extract potential LL of managerial nature. The latter, once investigated and subjected to an impact analysis, could be translated into real procedures or guidelines that can be shared inside and outside the process that has generated them. Currently, M-EPT is evaluating the feasibility of extending the proposed methodology to adapt it to its QMS processes by drafting a detailed procedure that can be shared with the entire BU.

Advantages

The advantages of implementing and systematizing a process for managing Lessons Learned for all QMS processes, through a specific procedure, are numerous. Firstly, using this methodology for past experiences would help reconstructing the dynamics that triggered the criticality under consideration. This procedure would bring to light the gaps and managerial root causes within the processes involved, that have not been investigated up to that moment. Similarly, by improving and extending the Lessons Learned management system to all QMS processes, team members can keep track of archived LLs and consult them for their exploitation in future projects. Another advantage of using Lessons Learned is having the opportunity to learn from positive experiences. In fact, it will be possible to discover the strengths of a project, disseminating them as a "best practice" for future activities. Furthermore, focusing on the LL creation process would increase tacit company knowledge and would ensure both the respect and the implementation of the prerequisite of continuous improvement.

Limitations

However, the process of generating Lessons Learned involves overcoming some obstacles, first the lack of involvement of employees. In fact, one of the main problems encountered during the reconstruction of the case studies concerned the involvement of the staff in openly explaining what happened. At the base, there is a lack of real awareness of the importance of negative experiences and their objective sharing. In fact, to share problems encountered by a negative experience, it is necessary to overcome the "fear" of feeling blamed for the problem occurred. Hence, it is necessary to try seeing the positive side, that is to preserve the experience, share it and prevent it from occurring and by avoiding to fall into the same mistakes. In order to overcome this limitation, “Lessons Learned awareness programs” could be introduced, in which the common goal is to give value to negative experiences and empower participants to detail what happened in a clear and objective way.

One of the other possible causes attributable to the lack of involvement of people about LL is the lack of time due to the heavy workload. The latter can be considered the main cause of another challenge for the company, i.e. the data collection process. Consequently, in the extension of the "Bottom-up" methodology, the candidate, in order to circumvent this challenge, introduces the figure of a mediator (LL Champion), who is responsible for coordinating the entire LL generation process and supporting the other team members in collecting data. The latter, supported by the reference process owner, will also be responsible for the entire process of sharing the LLs explained in Chapter 3.

Future developments

In Chapter 3, the candidate proposes a new methodology for generating LLs that could be developed in the future by the organization, in conjunction with the proposed extension of the "Bottom-Up" approach. Using a "Top-Down" approach for identifying possible LLs makes it possible to first analyze the critical and targeted KPIs, then to discover the possible causes attributable to the positive or negative experience. If critical KPIs are analyzed, the root causes could be brought to light and corrected, generating possible LLs to be applied so that it is possible to avoid the occurrence of problems that have not yet occurred but that could occur in the future. Due to both time and corporate privacy constraints, the candidate has not implemented real business case studies to explain the above approach. However, in the illustrative chapter of the "Top-Down" methodology, a practical and general example was implemented, which resulted in the feasibility of the approach, since the candidate was able to extract possible managerial LLs from the analysis of a generic KPI hypothesized out of target.

Moreover, a possible proposal to improve the extension of the "Bottom-up" methodology could be the implementation of a format for collecting data, specific for each process in an anonymous format. To overcome the limitations described above, regarding the lack of involvement of people, annual awards could be introduced for employees who have actively and objectively participated in the process of generating Lessons Learned.

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