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Efficiency and effectiveness improvement of quality management in an automotive company

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DECLARAÇÃO

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ABSTRACT

This master dissertation was developed in Bosch Car Multimedia in Braga, more specifically at the Center of Competence of Printed Circuit Boards (PCBs) – CM/MFT3 section. The main objective is to analyze the section processes and establish the conditions for identify and implement efficiency and effectiveness improvements. Thus, four activities were settled: data collection and definition of the processes performed by the section with a detailed description of their main activities and corresponding responsible; processes' flowchart elaboration; definition of key performance measures and indicators for critical factors of each process; and implementation of performance measures.

To accomplish the main objective, firstly, a literature review was done in order to understand the literary context. The themes reviewed were centered in quality management, quality standards, quality tools and performance measurement.

Secondly, to have a better understanding of the context of Bosch Group, the Car Multimedia and, specially, the Center of Competence of PCBs – CM/MFT3 section, a research in Bosch internal database was done. However, to understand in more detail the section main activities and processes, a guideline was developed and the persons responsible of the activities of processes were inquired.

The next steps were the development of the processes flowcharts and description, definition of their objectives and, in accordance with them, define the performance measures that enable the processes monitoring.

All the proposed objectives for this master dissertation were successfully applied, bringing, on one hand, the necessary formalism and standardization for the processes of the section and a clear way of relate them, and on the other hand, the essential processes monitoring and the evaluation of their efficiency and effectiveness.

KEYWORDS

Quality management; Quality tools; Performance measurement.

RESUMO

A presente tese de mestrado foi desenvolvida na Bosch Car Multimedia, mais especificamente no Centro de Competência de *Printed Circuit Boards* (PCBs) – secção CM/MFT3. Com o objetivo principal de analisar os processos da secção e estabelecer as condições para identificar e implementar melhorias de eficiência e eficácia, quatro atividades foram definidas: recolha de dados e definição dos processos desenvolvidos na secção com uma descrição detalhada das suas atividades principais e respetivo responsável; elaboração dos fluxogramas dos vários processos; definição de medidas e indicadores de desempenho para a monitorização de fatores críticos dos diferentes processos; e, ainda, implementação das medidas de desempenho definidas.

De forma a ser atingido o objetivo principal, primeiramente, foi realizada uma revisão da literatura com o objetivo de contextualizar os assuntos a serem abordados. Os temas tratados envolvem assuntos como gestão da qualidade, normas da qualidade, ferramentas da qualidade e medição do desempenho.

Posteriormente, para melhor compreender o contexto do Grupo Bosch e da divisão Car Multimedia foi realizada uma pesquisa na base de dados interna. No entanto, para compreender com mais detalhe as atividades e processos, concretamente, em relação ao Centro de Competência de *Printed Circuit Boards* (PCBs) – secção CM/MFT3 foi elaborado um guião específico e os responsáveis pelas atividades dos processos foram inquiridos.

Os próximos passos consistiram em descrever e elaborar os fluxogramas do estado atual dos processos, definir os seus objetivos e, de acordo com estes, definir as medidas de desempenho de forma a poderem ser monitorizados.

O objetivo proposto foi atingido com sucesso, proporcionando, por um lado, a necessária formalização e standardização dos processos e uma forma clara de os correlacionar, assim como a sua essencial monitorização e a avaliação da sua eficiência e eficácia.

PALAVRAS-CHAVE

Gestão da qualidade; Ferramentas da qualidade; Medição do desempenho.

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LIST OF ABBREVIATIONS

AIT area	Assembly Interconnection Technologies and Reliability area
BANF	Purchase requisition
BGN	Bosch GlobalNet
BrgP	Braga, Portugal
CM	Car Multimedia
CoC	Process owner
CP	Control Plan
CPR	Component Processability Release
CPR area	Component Processability Release and Footprint Design area
DoE	Design of Experiments
EDS	Energy Dispersive X-ray Spectroscopy
FMEA	Failure Mode and Effect Analysis
IMA	Industrialization Maturity Assessment
IND area	Industrialization Process and Plant Support area
ISO	International Organization for Standardization
KPI	Key Performance Indicator
MAE	Machinery And Equipment
NICE	Internal Number of Equipment Control
OPL	Open Point List
PCB	Printed Circuit Board
PCDA cycle	Plan-Do-Check-Act cycle
P-FMEA	Process Failure Mode and Effect Analysis
PMO area	Project Management Office area
PMS	Performance Measurement System
PRE	Process Rules for Engineering
PRP	Process Rules for Production
QFD	Quality Function Deployment
QGC	Quality Gate Costumer
QMS	Quality Management System
SEM	Scanning Electron Microscopy
SPC	Statistical Process Control
STA	Simultaneous Thermal Analysis
TG	Technology Gate
TIF	Thermal Impact Factor
WI	Work instruction
YTD	Year-to-date

1. INTRODUCTION

The present dissertation was developed under the scope of the Master in Quality Engineering and Management from the University of Minho. This dissertation was developed in the CM/MFT3 section of Bosch Car Multimedia in Braga and the current chapter presents the motivation, objectives and structure for this master dissertation likewise the methodology selected for its development.

1.1 Motivation and background

There are two important meanings for quality. Oriented to income, quality means "those features of products which meet customer needs and thereby provide customer satisfaction". Oriented to costs, quality means "freedom from deficiencies and errors that require rework or that result in field failures, customer dissatisfaction and customer claims" (Juran & Godfrey, 1999).

To obtain quality, it is well to begin by establishing the vision for the organization, policies and goals. Making quality happen, that consists of convert goals into results, is then done through managerial processes that involve a sequence of activities that produce the intended results. Managing for quality makes extensive use of three such managerial processes known as the Juran trilogy: quality planning, quality control; and quality improvement. Quality planning is a "structured process for developing products (both goods and services) that ensures that customer needs are met by the final result". Quality control is a "universal managerial process for conducting operations so as to provide stability to prevent adverse change". "To maintain stability, the quality control process evaluates actual performance, compares actual performance to goals and takes action on the difference". Quality improvement is "the organized creation of beneficial change and the attainment of unprecedented levels of performance" (Juran & Godfrey, 1999).

Over the years many new concepts, tools and methods have been introduced (Godfrey & Kenett, 2007). The evolution of the quality concept, its organizational impact, the introduction of new ISO standards and the diffusion of quality awards have increased the importance of implementing performance measurement to support the decision making processes, that indicates the degree of accomplishment of objectives and, therefore, quantifies progress toward the attainment of goals and monitors the continuous improvement process, which is central to the changes required to become competitive (Garengo et al., 2005; Juran & Godfrey, 1999).

Bosch Car Multimedia has, among others, the objective of remaining competitive in the market, investing increasingly in the development of new projects and processes in the automotive industry. This development and subsequent growth, particularly at CM/MFT3 section of BrgP/MOE1 department,

brings additional difficulties on resources management, planning and quality in general. The lack of information about processes (and projects related) of the CM/MFT3 and the necessity for measuring the performance and evaluating the quality of services provided by the section are the main motivations that will lead this master dissertation.

1.2 Objectives

The main objective for this master dissertation is to analyze the section processes and establish the conditions for identify and implement efficiency and effectiveness improvements. To be possible to achieve this objective, different activities have to be performed:

- data collection and definition of the processes performed by the section with a detailed description of their main activities and corresponding responsible;
- processes' flowchart elaboration;
- definition of key performance measures for critical factors of each process;
- implementation of performance measures.

1.3 Research methodology

Research strategy is chosen based on objectives, knowledge, time and available resources (Saunders et al., 2009).

There are seven types of research strategies that could be adopted:

- Experiment;
- Survey;
- Action research;
- Grounded theory;
- Ethnography;
- Archival research;
- Case study.

Case study, specifically, is one way of doing social science research in which the investigator has little control over events. It can also be described as an involvement of an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence. This strategy tries to illuminate a decision or a set of decisions: why they were taken, how they were implemented and with what result (Yin, 2009; Saunders et al., 2009).

There are at least four different applications for case studies. The most important is to explain the presumed causal links in real-life interventions. A second application is to describe an intervention and

the real-life context in which it occurred. Third, case studies can illustrate certain topics within an evaluation in a descriptive mode. Fourth, the case study strategy may be used to elucidate the situations in which the intervention being evaluated has no clear single set of outcomes (Yin, 2009; Saunders et al., 2009).

Considering these topics and since action research strategy comprises iterative cycles of collecting data, analyzing the data, planning action, taking action and evaluating which involve a long period of implementation that is not available during this master dissertation, case study was the one adopted (Coughlan & Coghlan, 2002; Gephart, 2004).

The terms quantitative and qualitative are widely used to differentiate both data collection techniques and data analysis procedures and, thus, are associated to the research strategy. One way of distinguishing between the two is the focus on numeric (numbers) or non-numeric (words) data. While quantitative is predominantly used as a synonym for any data collection technique (such as a questionnaire) or data analysis procedure that generates or uses numerical data, qualitative is used as a synonym for any data collection technique (such as an interview) or data analysis procedure that generates or use non-numerical data (Saunders et al., 2009).

Qualitative research uses an interpretive and naturalistic approach and is often designed at the same time it is being done, offering a holistic representation of reality that cannot be reduced to a few variables like happens in quantitative method (Gephart, 2004).

Quantitative methods, on the other hand, offers numbers and statistics and seek to collect abundant data in a timely and profitable way (Sallee & Flood, 2012).

When a single data collection technique and corresponding analysis procedure is used, means that a mono method is being used. Thus, when more than one data collection technique and analysis procedure are used, multiple methods will be used. Therefore, if both quantitative and qualitative techniques and procedures are adopted, a mixed methods procedures are used in the research process (Saunders et al., 2009).

This master dissertation development was based in a mixed methods approach, since it was adopted qualitative methods to data collection and quantitative methods to analysis procedures.

Time horizon, on the other hand, is independent of research strategy, however it can be characterized as longitudinal or cross-sectional (Saunders et al., 2009).

Cross-sectional research is characterized by the study of a specific phenomenon at a particular time. Cross-sectional studies seek to describe the frequency of a phenomenon or to explain how factors are related (Saunders et al., 2009).

Longitudinal research, in turn, has to present these three characteristics: data collection, for the same variables, has to have at least two distinct time periods duration; the subjects in the different data collection has to be the same or at least comparable; the statistical analysis has to involve some kind of comparisons between, or among, the periods (Siegrist, 2014).

Bearing in mind that most of the research to academic projects are necessarily time constrained, cross-sectional studies were the adopted for this master dissertation.

1.4 Structure

The present dissertation is divided into seven main chapters.

In the first chapter is presented the motivation and background, the objectives that promoted the written of this master dissertation, as well as the research methodology that was used to develop the proposed objectives.

In the second chapter the literature review is presented to introduce the themes that will be focused over the dissertation.

In the third chapter, Bosch Group and, specifically, the Car Multimedia division in Portugal (Braga) are presented. CM/MFT3 is also described since it is the section where this master dissertation was developed.

The fourth chapter presents the CM/MFT3 processes mapping, while in the fifth chapter are described the processes performance measures defined based on the processes objectives. The sixth chapter describes the monitoring of the section processes according to the performance measures established for each one.

At last, the seventh chapter addresses the conclusions and final considerations about the work done, its limitations, as well as suggestions for future work.

2. LITERATURE REVIEW

In this chapter a literature research about the relevant topics to this master dissertation elaboration was developed. Themes like quality definitions and evolution over time until Total Quality Management (TQM), quality standards, tools and techniques will be discussed likewise performance measurement systems and performance measures as a mechanism to quantify efficiency and effectiveness.

2.1 Quality concepts and evolution

In a market economy, each organization is competing with others providing the same product. This principle is valid independent of the type of offer, including material goods as well as immaterial services or their combination. Thus, the survival of an enterprise depends on its ability to gain and enthuse customers. To assure the fitness of an organization in this competition, it is necessary to provide quality (Weckenmann et al., 2015).

There are a wide variety of definitions proposed for quality. Webster's New World Dictionary defines quality as a "physical or nonphysical characteristic that constitutes the basic nature of a thing or is one of its distinguishing features" (Kolarik, 1995). However, quality applied to the products turned out by industry, is characterized, according to Radford, as "the characteristic or combination of characteristics which distinguishes one article from another, or the goods of one manufacturer from those of his competitors, or one grade for product from a certain factory from another grade turned out by the same factory" (Banks, 1989).

Shewhart, on the other hand, supports that "there are two common aspects of quality, one of these has to do with the consideration of the quality of a thing as an objective reality independent of the existence of man. The other has to do with the subjective side of thinking, feeling or sensing as a result of the objective reality" (Shewhart, 1980).

In addition to the definitions mentioned, another ones were recognized. For Juran, oriented to incomes, quality means "those features of products which meet customer needs and thereby provide customer satisfaction", however, oriented to costs, quality means "freedom from deficiencies – freedom from errors that require doing work over again (rework) or that result in field failures, customer dissatisfaction, customer claims and so on" (Juran & Godfrey, 1999). Bearing this in mind, a short phrase that "clearly and simultaneously defines both the major meanings" is "fitness for use" (Juran & Godfrey, 1999). For Crosby, quality is "conformance to requirements" (Crosby, 1982). For Deming, quality "should be aimed at the needs of the consumer" (Deming, 1986). For Feigenbaum, quality is "the total composite product and service characteristics of marketing, engineering, manufacture and maintenance through which the

product and service in use will meet the expectations of the costumer" (Feigenbaum, 1991). Quality has also been described by Taguchi that offered a "generalized definition for quality of performance" (Roy, 2001). For him, quality is "consistency of performance around the target" and if "the performance is consistent, variation around the target is reduced", since "a reduced variation results in a reduction in scraps, less rejection of product and a fewer warranty returns, consequently reducing costs and improving customer satisfaction" (Roy, 2001).

The first paradigm of quality came up during the period of mass production (1900 to 1940). At that time, activities of quality inspection focused only on the delivery of manufactured products without known failures. The essential aim was to assure a merely sufficient quality of delivered products and thus avoid complaints from customers. As a main method to achieve this, final products were inspected and waste was filtered out. Subsequently, these activities were introduced as quality inspection as an additional, final working step (Weckenmann et al., 2015).

The necessity for extensive inspections resulted in high costs and also high waste rates. As an effort to reduce the increasing costs, it was tried to maximize the benefits of mass production, meaning less product variety with high product volume. Customer needs were hardly considered. The market competition was marked by the effort to provide products of sufficient quality as fast and cheap as possible in order to prevail over competitors and increase the own gaining (Weckenmann et al., 2015).

Under increasing economic pressure (after 1940), the main focus changed from product quality to process quality and the manufacturing processes were taken into consideration to enable a control of production, especially in order to reduce the high loss and waste resulting from the so far established inspection concept (Weckenmann et al., 2015).

The widened focus on the whole process came along with the understanding that the looking for errors and their subsequent correction was much less efficient than to find the source of the errors and remove that. Resulting, it was no longer aimed to merely inspect quality and react, but to control quality. Defined as a system of means whereby the qualities of products or services are produced economically to meet the requirements of the purchaser, quality control was supported by a variety of methods like the seven tools of quality, the plan-do-check-act cycle (PDCA cycle) and the "five whys" strategy came up to support the identification and correction of errors (Kolarik, 1995; Weckenmann et al., 2015). Additionally, the focus on process quality enabled the utilization of statistical methods on practical problems, resulting in the definition and wide-spread use of statistical process control (SPC) to react on changes in time and to avoid the production of waste. Complementary, statistical design of experiments (DoE) came up,

facilitating the efficient identification and adjustment of significant input parameters to gain optimal output results (Weckenmann et al., 2015).

Starting from around 1960s, quality assurance was implemented to not just control the quality of products and processes and react subsequently, but assure quality in advance by identifying possible risks and problems and preventing them before they came up. Thus, defined as all planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality, quality assurance was oriented to preventive actions (Weckenmann et al., 2015; Kolarik, 1995).

At 1980, the concept of costumer focus started to be commonly established. By this quality customer-oriented planning, the prevention of the most crucial problem was possible (Weckenmann et al., 2015).

Along with the rising demands of customers enabled by the competition, complexity of products increased dramatically and because of that, interdependencies inside an organization and with suppliers had to be considered. With the increased complexity of entities and their relationships, a system-oriented view including not only the linear dimension of a value-creation process but also, as a second dimension, its connections and interdependencies with all other processes and activities in the organization documentation and activities for mutual trust between partners became needed. This leads to a new paradigm that resulted in the issuing of the series ISO 9000, defining basic requirements for quality management. Together with this standardization, the possibility and demand for certification came up, allowing a system of suppliers and industrial customers to trust on the quality-oriented performance of a partner (Weckenmann et al., 2015).

What happened in the quality world in the 1990s was that techniques and tools took the lead, while the organizational transformations that were supposed to be at the core of the new management philosophy were postponed, moved to the background and, little by little, almost forgotten (Conti, 2010). It has to be stated that the major advances of quality management have not been achieved by issuing new techniques or methods, but by creating a common harmonized and internationally accepted framework of standards and accredited certification agencies, enabling mutual trust and better partnerships of enterprises (Weckenmann et al., 2015).

The influence of employees as opposed to machines or other technical components plays an ever more important role. Thus, the need for commitment of all employees in an organization leads to the paradigm of Total Quality Management (TQM) after recognizing the relationships between leadership, employee, processes, customer satisfaction and business results. Due to this identified relations, the Total Quality Management and business excellence models raised up (Weckenmann et al., 2015).

Figure 1 summarizes the development of quality eras.

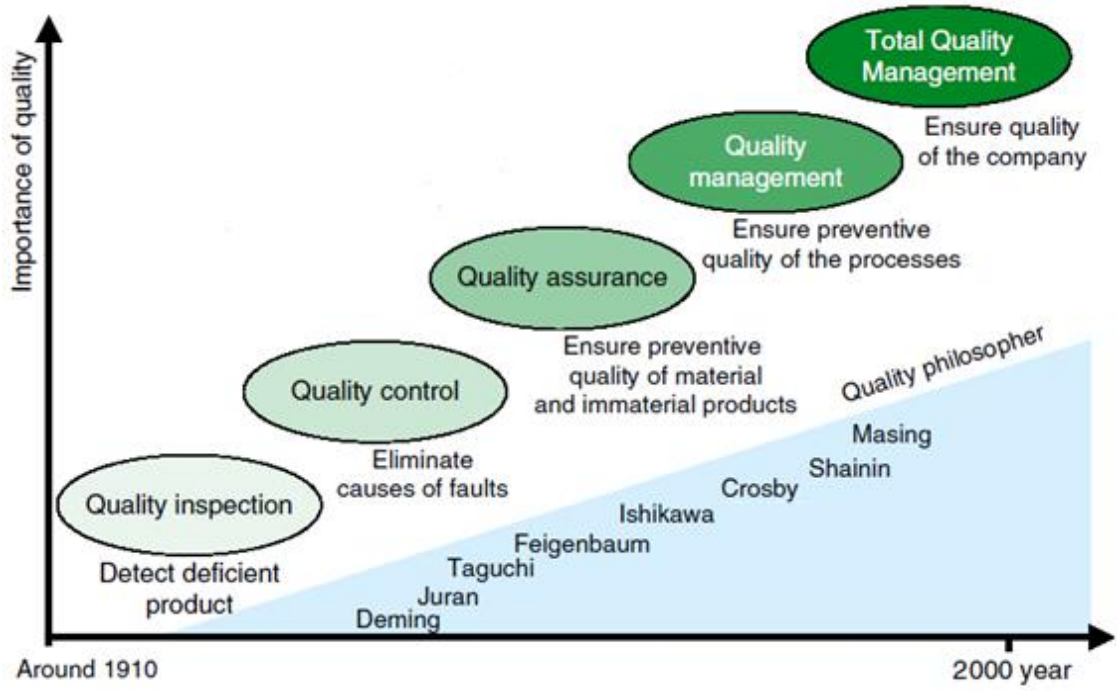


Figure 1 – Concepts in quality (adapted from Weckenmann et al., 2015).

2.2 Total Quality Management

Every business wants to produce better products and deliver services faster, more efficiently and to better quality standards. In their quest to do this, many organizations were forced to implement some fundamental quality principals (Hannan, 1991).

Deming proposed fourteen principles to improve quality in organizations based on the following ideas: leadership; the right production from the beginning; training for managers and employees; internal communication aimed at the elimination of obstacles; and the suppression of quantitative objectives (Deming, 1982; Deming, 1986).

According to Juran, the aim of management is to reduce the cost of mistakes, reaching a point where the total costs of quality are minimal. Thus, he pointed out the importance of both technical and managerial aspects and identified the three basic functions of the quality management process: planning, organization and control as the stages for quality improvement (Juran, 1986).

Ishikawa emphasized the importance of training, the usage of cause-effect diagrams for problem solving and quality circles as a way to achieve continuous improvement, while Crosby defined fourteen steps for quality improvement, including top and intermediate management commitment, quality measurement, evaluation of quality costs, corrective action, training, a zero-defect philosophy, objective setting and employee recognition (Ishikawa, 1976; Ishikawa, 1985; Crosby, 1979). Lastly, Feigenbaum highlighted

aspects like leadership and quality improvement as a commitment to incorporate quality in the organizations practices (Feigenbaum, 1991).

The research by all these authors shows both strengths and weaknesses but none of them offers the solutions to all the problems identified by organizations, thus rising Total Quality Management (TQM) that was progressively developed from these initial contributions (Tarí, 2005).

TQM started in the USA when Hewlett-Packard criticized United States of America (USA) chips manufacturers for poor product quality when compared to their Japanese competitors. When TQM was introduced, the Japanese adopted the philosophy while the USA rejected its principles. While the Japanese, very successfully, made progress with quality and production by adopting the TQM principles, it was only later that this philosophy was implemented in USA (Talha, 2004).

TQM refers to a management philosophy including tools and methods used to enhance quality and productivity in organizations. The basic principles of TQM are intended to achieve continuous organizational improvement through the participation and commitment of all its employees that do the best possible job to satisfy the customer requirements. TQM focuses on ensuring that all the resources of an organization are employed strategically toward meeting the needs of its customers, using statistical tools and techniques to measure results and aid decision making. It involves all the departments and employees, focusing on continuous process improvement within the organization, so as to provide superior customer value and meet or exceed customer expectations (Chen et al., 2016; Talha, 2004).

TQM means that the organizations' culture is defined by the constant achievement of customer satisfaction through an integrated system of tools, techniques and training. This involves the continuous improvement of organizational processes, resulting in high quality products and services (Talha, 2004). In other words, it is an integrated effort to achieve and preserve high-quality products based on the maintenance of continuous process improvement and error prevention (Jiménez-Jiménez et al., 2015).

TQM encourages cost reduction, the creation of high quality goods and services, customer satisfaction, employee empowerment and the measurement of results, incorporates the concepts of process control, quality assurance and quality improvement and can be studied from three different approaches: contributions from quality leaders; formal evaluation models; and empirical research (Talha, 2004; Tarí, 2005; Vanichchinchai & Igel, 2009).

A simple model for TQM consists of two main components: philosophy; and systems/tools. TQM cannot exist without a complete acceptance of its philosophy by, at least, the top management. Once the basic TQM philosophy is accepted by the top management, then different systems and tools can be initiated to propagate and facilitate a culture based on TQM (Khan, 2003; Fonseca, 2015).

To summarize, the literature points out some underlying implicit agreements concerning the definition, scope and the core principles and concepts of TQM (Fonseca, 2015):

- top management commitment and leadership;
- continuous improvement;
- focus on customers;
- total involvement, total commitment and total responsibilities;
- actions based on facts;
- focus on processes;
- focus on employees, teamwork, motivation and empowerment;
- focus on learning, training and education;
- building partnership between suppliers, customers and society;
- systematic approach on building a TQM culture.

TQM comprises not only the continuous process improvement but also the standardization of quality systems. Both these elements work together to provide an overall increase in business performance (Hannan, 1991).

Recent studies investigated the relationship between TQM practices and organization performance. Most of them support that TQM "improves business performance both internally (higher productivity) and externally (customer satisfaction) and leads to market share increase and long-term profitability" (Psomas & Pantouvakis, 2017). However, several other studies reported that TQM companies' implementation have failed entirely or have created problems serious enough mainly because of an organization's culture neglect (Valmohammadi & Roshanzamir, 2015).

TQM-adopting organizations obtain a competitive advantage over organizations that do not adopt TQM. Organizations that focus on continuous improvement, involve and motivate employees to achieve quality output and focus on satisfying customers' needs, are more likely to outperform (Valmohammadi & Roshanzamir, 2015). Nevertheless, cultural change is essential for the successful implementation of TQM (Valmohammadi & Roshanzamir, 2015).

2.3 Quality standards

As already mentioned, TQM is presented as a holistic philosophy which engenders a customer orientation, an employee and customer empowerment, attention to processes and a continuous improvement. It is essentially a way of organizing and ensuring the participation of the entire company (Chen et al., 2016). To accomplish the company organization and ensure the entire company commitment, ISO (International Organization for Standardization) certification grew a lot within the last twenty years and a pillar of today's

quality movement is the ISO 9000 series of international standards. These quality standards started to be published by ISO in 1987 as a key tool to allow the growing of internationalization of business (Kompalla & Kopia, 2015; Fonseca, 2015).

Quality standards were established to "create concepts, guidelines, principles and certain criteria for establishing, operating and improving all processes with which an organization achieves its goals" (Kompalla & Kopia, 2015). They present a sequence of steps intended to increase business efficiency and customer satisfaction, thus helping organizations meet the needs of customers and other stakeholders as well as the regulatory requirements related to their products or services (Chen et al., 2016).

Quality standards "decrease the gap between the current quality management environment and TQM for the majority of the organizations, offer a shift in focus from the final products to the processes that produce these products, improve internal organization and operation, ensure a more effective and uniform communication throughout the organization, increase employees' awareness in quality issues, lower quality variations and quality related costs, increase customers' satisfaction and trust to the company and encourage continuous improvement through regular and imperative quality audits" (Gotzamani & Tsiotras, 2001).

In order to receive a certificate of compliance, organizations must meet a set of requirements. In this process, independent auditors from third parties determine if the standards have been met and issue a certificate of compliance if the organization met the requirements (Farinha et al., 2016).

ISO has a directive governing the publication of standards (to be reviewed every five years). Sometimes the review confirms there is no change but are not the majority of the cases (Fonseca, 2015). Particularly, ISO 9001 standard (Quality Management Systems – Requirements) was first published in 1987 and then revised in 1994, 2000, 2008 and 2015 (Farinha et al., 2016).

The ISO 9001 standard does not refer to fulfilment of an objective or the attainment of a particular result. It is not a performance standard measuring the quality of companies' products or services. Rather, it establishes the need to systemize and formalize a series of procedures. Being ISO 9001 compliant means having implemented a Quality Management System (QMS) that draws together in standardized and documented procedures (Heras-Saizarbitoria et al., 2011).

ISO 9001 standardizes procedures, duties and roles, providing cost savings, enhanced customer satisfaction, access to new markets and increased market share (Chen et al., 2016; Heras-Saizarbitoria & Boiral, 2013).

ISO 9001 last revision, released in September of 2015, uses the new harmonized high level structure that has been developed by ISO's Joint Technical Coordination Group, and published in Annex SL of the ISO directives. This will make life easier for organizations that choose to have a single (integrated) management system to meet the requirements of multiple standards (Croft, 2015).

The new version of ISO 9001 places much more emphasis on the service sector, by making the overall language of the standard more user-friendly for service organizations, and adapting some of the traditional clauses to focus more on the needs of the service sector. Gives more attention to requirements related to service design and development, and "measuring equipment" as it relates to the service sector. The standard will now specifically use the terminology "products and services" instead of just "products", as before (Croft, 2015).

A strong emphasis on the "process approach" that has been so successful in the 2000 and 2008 versions of the standard is maintaining and a new concept on "risk-based thinking", whereby an organization needs to identify the risks and hence the opportunities associated with their activities and take steps to reduce the risks of producing non-compliant products and services, has been established as well as the increase of leadership requirements (Croft, 2015; Farinha et al., 2016; Medic et al., 2016).

ISO 9001:2015 fundamental pillars could be summarized in these seven principles of quality management (Conti, 2010; NP EN ISO 9000:2015, 2015):

- customer focus – the primary focus of quality management is the satisfaction of customer requirements and the effort to exceed their expectations;
- leadership – leaders establish, at all levels, unity in purpose and direction and create the conditions for people to commit themselves to achieving the organization's targets;
- commitment of people – it is essential for the organization that people are competent and equipped with the respective authority to make decisions independently and committed to add value to the organization;
- improvement – organizations that succeed are constantly focused on improvement;
- decision making evidence-based – decisions based on analysis and evaluation of data and information are more likely to produce the desired results;
- relations management – to have sustained success, organizations generate its relations with stakeholders, such as suppliers;
- process approach – consistent and predictable results are achieved more effectively and efficiently when activities are understood and managed as interrelated processes that act as a coherent system. According to ISO 9000:2015, a process is a set of interrelated or interacting

activities that transform inputs into the desired outputs. The organization defines the various inputs necessary for the effective implementation of the process and the expected outputs. Processes are usually interconnected and the output of a process typically serves as input in another (Farinha, et al., 2016). The understanding that processes are part of systems reveals the fundamental role of relations. Brief annotations can be found in ISO 9000 standards and excellence models that reveal that relationship among processes should also be taken into account. However, attempts to transform functional organizations into process-based organizations often failed because they jumped from one extreme to the other. The systemic nature of the organization, its relations and its subsystems, is also important to be considered.

With more than 1.1 million certificates issued worldwide, ISO 9001 is the standard used and all the changes introduced in the 2015 revision are intended to ensure that ISO 9001 continues to adapt to the changing environments in which organizations operate (Farinha et al., 2016; Medic et al., 2016).

2.4 Quality tools and techniques

According to Deming when the quality is improved, the cost decreases (because of less rework, fewer mistakes, fewer delays and better use of machine, time and material), when cost decreases productivity improves, when productivity improves industries capture the market with better quality and low price and in this way, enhance the business and provide more jobs (Deming, 1986).

No one can deny the importance of quality especially in such a competitive market where only survive, who can provide better quality products (Muhammad, 2015).

The seven quality tools were developed independently of each other's, however they were first popularized by Ishikawa during the quality revolution in Japan. Ishikawa did not invent all of these tools, some of these were already in use since 1900s, but he took all these seven tools and made a set of them and named it "the basic seven tools of quality". These tools are also known as basic quality tools because they are suitable for people and require less formal training statistics and also because they can be used to solve the vast majority of quality-related issues (Muhammad, 2015; Ishikawa, 1985).

Tools and techniques are practical methods, skills, means or mechanisms that can be applied to particular tasks. Among other things they are used to facilitate positive changes and improvements (McQuater et al., 1995).

A single tool may be described as a device which has a clear role and a way to solve a problem. It is often narrow in focus and is usually used on its own, since on its own is enough to produce positive results in a limited area. The basic seven quality tools are (Muhammad, 2015; Kolarik, 1995):

- flowchart – provides a graphical or symbolic picture of the process, showing the whole process step wise from beginning to end, how the elements interrelate, alternative paths the process can take and how the process translates inputs into outputs. The main objectives are to study and control the process and identify the existing problems;
- check sheet – is a simple tool used to record and classify observed data. Is used to collect data and record which process occurs and how many times;
- Pareto chart – consists of simple series of bars whose height indicate the impact of defects/problems, showing variables in graphical form in descendent order. The Pareto principle, applied to quality, suggests that the majority of the quality losses are poorly distributed in such a way that a vital quality defects or problems always constitute a high percent of the overall quality losses;
- histogram – is a graphical representation of numeric data, used to show how often each different value in a set of data occurs;
- cause and effect diagram – used to figure out the root causes of a problem in order to try to find out the reason of every cause which makes the problem happen. A cause is a fundamental condition or stimulus of some sort that ultimately creates a result or effect;
- scatter diagram – also known as X-Y plot, provides the opportunity to view a data set in multiple dimensions in order to detect trends, spot best operating regions and explore cause-effect relationships. Is used for paired numeric data and relates two variables where independent variable is plotted on X-axis and dependent variable is plotted on Y-axis;
- control chart – is used to study the variation of a process with time and check process stability. Has two control limits that define boundaries for minimum and maximum values and once an indication of a process shift is detected, special cause(s) should be localized and corrective action taken.

Some new quality control tools have emerged, which are mostly used with qualitative data: affinity diagram; relation diagram; tree diagram; matrix diagram; arrow diagram; process decision program chart (PDPC); and matrix data analysis (McQuater et al., 1995; Muhammad, 2015; Ismyrlis & Moschidis, 2015). Quality tools can be used at all stages of the product development and production, with the primary goals of cost reduction and customer satisfaction. These tools are considered to be the simplest and easiest tools that one can use to improve the quality of industrial processes since no special skills or huge capital is required to use them (Muhammad, 2015).

A technique, on the other hand, has a wider application than a tool and may include many tools. This often results in a need for more thought, skill and training. Viewed simplistically, techniques can be thought of as a collection of tools. Examples of techniques are: Benchmarking; design of experiments (DOE); Failure Mode and Effect Analysis (FMEA); SWOT analysis; and Quality Function Deployment (QFD) (McQuater et al., 1995; Ismyrlis & Moschidis, 2015).

Tools and techniques play a key role in a company-wide approach to continuous improvement. They allow processes to be monitored and evaluated, engagement in the continuous improvement process, a transfer of experience from quality improvement activities to everyday business operations and a reinforcement of teamwork through problem-solving (McQuater et al., 1995; Bunney & Dale, 1997).

The purpose of all tools and techniques is to convert apparent chaos into a workable, implementable action plan. These tools and techniques, thus, provide mainstream managers with a systematic approach to innovation requiring the conversion of raw creativity into real change (Anjard, 1995).

Tools and techniques can become very powerful by combining them into a cycle of activity in which the output of one tool or technique becomes an input into the next tool or technique. For example, when a Pareto analysis provides the focus for a cause and effect diagram which then in turn provides the focus for control charts. Each of the tools or techniques can be used alone very effectively, however the full effect is achieved when they are used together to move away from a chaotic situation to an implementable action plan for improvement (Anjard, 1995).

The use of quality management tools and techniques is a very important and crucial factor because is the mean for the appropriate implementation of a quality program (Ismyrlis & Moschidis, 2015).

2.5 Performance measurement

2.5.1 Performance measurement systems and performance measures

In order to proactively answer to all the challenges to succeed, management requires accurate performance information. However, despite the amount of research and development in performance measurement, systems that are properly integrated, dynamic, accurate, accessible and visible to facilitate responsive manufacturing and services are still not common (Nudurupati et al., 2011).

Performance measurement is the process of quantifying efficiency and effectiveness of actions within a business context, where effectiveness is the agreement with customer requirements and efficiency is how the organizations' resources are used to achieve customers' satisfaction levels (Braz et al., 2011).

To ensure performance measurement, which is an activity that managers perform in order to reach predefined goals that are derived from the organization's strategic objectives, performance measures should be chosen, implemented, and monitored. Performance measures are the metrics used to quantify

the efficiency and/or effectiveness of a part of or a whole process, or system, against a given norm or target (Lohman et al., 2004).

While performance measurement is the activity of measuring performance using performance measures or key performance indicators (KPIs), which are a combination of different performance measures, a performance measurement system (PMS) is a system, like software, database and/or procedure, to execute performance measurement in a consistent and complete way (Lohman et al., 2004).

Performance measures are essential elements for planning and control cycles but if the number of performance measures is too large and there are not any real need for the information generated, the decision-making and control processes could be hampered. Apart from data need, it is also important to consider data availability in the design stage of PMS because it is useless to design a PMS in which data are difficult to obtain or are unavailable (Braz et al., 2011).

The PMS design phase is about identifying key objectives and designing performance measures. After design phase, follows implementation phase that requires the development of procedures to collect and process data that enable the measurements to be made regularly. Last of all, in the use phase, managers review the measurement results to assess whether operations are efficient and effective (Lohman et al., 2004; Braz et al., 2011).

There are a general agreement about the main characteristics for performance measures and KPIs. They should be quantitative and have objective values instead of subjective ones. They should be straightforward and easy to understand to enable a quick identification of what is being measured and how it is being measured, practical and with appropriate scales, consistent and maintain meaning over time and clear on the objectives (Braz et al., 2011).

Another important consideration is defining performance measures attributes. Designing a performance measure involves more than just providing a complex formula. Issues, such as the meaning of the measure, the frequency of the measurement and the source of the data, should be considered as Figure 2 shows (Braz et al., 2011).

Attribute	Description
Name	Effective names to avoid ambiguities. A good name explains the meaning of the measure and defines why it is important.
Objective/purpose	The relationship between the measure and the objectives should be clear.
Scope	Business areas or parts of the organisation measured.
Targets	The objectives of the organisation to be attained.
Formula calculation	The precise calculation of the measure should be known. This formula represents the way in which the performance will be measured.
Units of measurement	The units of measurement used.
Frequency of measurement	The frequency of measurement recording and report preparation. It is related to the importance of the measure and the volume of data available.
Frequency of review	The frequency with which the measures are reviewed.
Source of data	The real source of data to calculate the measure. This source has to be consistent.
Person responsible for the measurement	Person in charge of collecting the data and reporting the measure.
Person responsible for the measure	Person in charge of achieving better performance.
Person responsible for the data	Person in charge of taking action based on data.
Drivers	The factors that influence performance.

Figure 2 – Performance measures attributes (Braz et al., 2011).

Performance measurement is based on the organization's strategy and aims to support the implementation and monitoring of strategic initiatives. The selection of performance measures and the setting of targets for these measures are seen as concrete formulations of the organization's strategic choices. Both financial and non-financial measures are needed to translate the strategy into specific objectives. The actual results achieved for the various measures reflect how well the organization succeeds in achieving these strategic choices. Reviewing the actual versus planned results may lead to take corrective actions in order to increase the probability of achieving the targets. But the results, on the other hand, may also lead to adjusting these targets and strategic choices (Lohman et al., 2004).

The comparison of desired performance measures with existing measures is important to identify which existing measures are kept, which existing measures are no longer relevant and which gaps exists so new measures are needed (Lohman et al., 2004).

2.5.2 Key performance indicators

The measurement tools that are used within the PMS to assess the performance of various processes are known as KPIs. As already referred, KPIs are defined as a combination of different performance measures and the concept behind their application is based on the concept of Benchmarking which involves measuring actual performances of some aspects of the business and comparing them with the best in the specific sector. Because the indicators are based on the comparison of actual performance

with the desired outcome, they can also be used as a basis for process or project control (Haponava & Al-Jibouri, 2012).

Organizations use KPIs at multiple levels to evaluate their success at reaching targets. In the past, financial indicators were largely considered in PMS, however current performance measurement is based on both financial and non-financial indicators due to its multidimensional structure (Kucukaltan et al., 2016).

The excessive use of financial measures that are not consistent with today's business realities was much criticized, prompting organizations to implement non-financial measures that appropriately reflect their objectives and to take a balanced measurement approach (Neely, 2007).

In this regard, a several measurement frameworks were designed to help organizations implement a balanced set of measures, leading to the development, for example, of Balance Scorecard (BSC) (Neely, 2007). These frameworks are multi-dimensional, focused more on non-financial information and designed to provide a balance by including measures of external success as well as internal performance, which give not only an early indication of future business performance but also a record of what has been achieved in the past (Bourne et al., 2000).

The need to use KPIs for improvement and learning purposes rather than for data comparison and the need for the measurements to include the soft aspects of process performance and not only the traditional aspects of time, cost and quality has been highlighted (Haponava & Al-Jibouri, 2012). KPIs such as technical requirements like quantity and quality, work conclusion on time and efficient use of the resources are reasonably easy to establish and trace. However, behavioral requirements are equally important as the technical requirements, but it is more difficult to deal with them (Sudnickas, 2016).

KPIs are fundamental managerial tools for decision-making in organizations and should be clearly distinguished from the factors determining the level of performance, which are no less important, however, are often confused with each other. The first are used to monitor performance, the latter, to improve it (Sudnickas, 2016; Kucukaltan et al., 2016).

An organization will typically identify an area where performance is to be measured and then brainstorm a list of indicators. It will then classify indicators into lead and lag depending on whether they represent cause or effect and begin reporting them. Specifically, lag are those measures which indicate progress towards corporate objectives and what is expected from the business. Lead are those measures which have a direct influence on the outcomes and are the drivers of outcomes (Walsh, 1996).

The lag indicators are the health barometers of an organization but when the outcomes have gone wrong it is too late for the organization to get through difficulties. Lag indicators identification occurs during

annual business planning when discussions center on the objectives the organization wishes to achieve during the forthcoming year and how it might measure progress. Too many organizations measure only lag indicators and never really know what is happening inside their key business processes (Walsh, 1996). The lead indicators, on the other hand, provide the means to run business operations. The driver-outcome relationship is more than just a lead-lag relationship. The striking difference is that the lead indicators are aligned with what happens inside business processes while the lag indicators are linked with what the business wants to achieve from business processes (Walsh, 1996).

One of the main shortcomings of existing KPIs is the fact that almost of all used are lagging which means that they are mostly used for review purposes after a process or a project is completed and, therefore, they do not offer the opportunity for control during the process or project development and execution. It is important to use indicators to measure performance while the process or project is running, only in this way control actions can be taken if necessary (Haponava & Al-Jibouri, 2012).

If the business is changing, early detection of changes is only possible through the lead indicators, so the focus of improvement efforts should be on the drivers not the outcomes. Improvement teams should spend their time examining the jobs and activities which influence the drivers. The lead indicators are found by opening up business processes and examining what can be measured within the processes which influence a desired outcome (Walsh, 1996).

There are numerous benefits of using KPIs. Some of them are (Kerzner, 2011):

- tell if the targets are hitting;
- catch mistakes before they lead to other mistakes;
- lead to informed decision making;
- assess performance accurately;
- allow proactive management in a timely manner;
- improve future estimating;
- make it easier to validate targets;
- assess success and failure;
- improve customer satisfaction.

3. Bosch Group

In this chapter the company Bosch, its divisions and, specifically, the CM/MFT3 section are described. The practices adopted in the section are, as well, exposed in order to contextualize and frame further subjects.

3.1 Bosch worldwide

The company was set up in Stuttgart in 1886 by Robert Bosch (1861-1942) as "Workshop for Precision Mechanics and Electrical Engineering." The Bosch Group involves Robert Bosch GmbH, its roughly 440 subsidiaries and regional companies in over 60 countries. Including sales and service partners, Bosch's global manufacturing, engineering and sales network covers nearly every country in the world (Bosch Worldwide, 2017).

Bosch has four business sectors (Figure 3): Mobility Solutions; Industrial Technology; Energy and Building Technology; and Consumer Goods (Bosch Worldwide, 2017).

Figure 3 – Bosch business sectors (Bosch Worldwide, 2017).

The Mobility Solutions business sector, in 2016, accounts for 58 percent of total sales. Its main areas of activity are injection technology and powertrain peripherals for internal-combustion engines, diverse solutions for powertrain electrification, steering systems, safety and driver-assistance systems, technology

for user-friendly infotainment as well as vehicle-to-vehicle and vehicle-to-infrastructure communication, repair-shop concepts and technology/services for the automotive aftermarket (Bosch Worldwide, 2017). This sector includes Gasoline Systems, Diesel Systems, Chassis Systems Control, Electrical Drives, Starter Motors and Generators, Car Multimedia, Automotive Electronics, Automotive Aftermarket and Automotive Steering divisions (Bosch Worldwide, 2017).

In the fiscal year of 2016, the Industrial Technology business sector generated roughly 10 percent of total Bosch Group sales. The sector includes Drive and Control Technology and Packaging Technology divisions. The Drive and Control Technology division specializes in drive and control technology and offers customized drive, control and solutions for factory automation, systems construction and engineering, mobile machinery and commercial vehicles. The Packaging Technology division provides process and packaging solutions for the pharmaceuticals, foodstuffs and confectionery industries, as well as selected segments of the beverages industry (Bosch Worldwide, 2017).

In 2016, the Energy and Building Technology business sector generated roughly 8 percent of total Bosch Group sales. Its Security Systems division develops products and solutions for video surveillance and access control, intruder and fire alarms, audio and conference systems and remote monitoring. Its Bosch Thermotechnology division supplies energy-efficient and increasingly web-enabled heating products and hot-water solutions (Bosch Worldwide, 2017).

The Consumer Goods business sector contributed with some 20 percent of total Bosch Group sales in 2016. It includes the Power Tools division that supplies power tools and power-tool accessories, as well as measuring and gardening tools. The main focuses of innovation are cordless tools and web-enabled tools. Also included in Consumer Goods business sector, Household Appliances division offers energy-efficient appliances such as stoves, ovens, dishwashers, washing machines, fridges and freezers and small appliances such as vacuum cleaners and coffee machines (Bosch Worldwide, 2017).

The objective of Bosch company is secure its future by ensuring a strong and meaningful development and preserve its financial independence (Bosch Worldwide, 2017).

To achieve the mentioned objectives, Bosch has different strengths based on (Bosch Worldwide, 2017):

- culture – Bosch distinct corporate culture is a common bond;
- innovation – creativity is the basis for new technological solutions;
- outstanding quality – met the customers' wishes and expectations and offer the best quality and reliability products;
- global presence – while constantly extending the global presence, local responsibility is strengthened.

As an international company, Bosch's values are sustained by (Bosch Worldwide, 2017):

- future and result focus;
- responsibility and sustainability;
- initiative and determination;
- openness and trust;
- fairness;
- reliability, credibility, legality;
- diversity.

Since 1887 the Bosch ignition has suffer some modifications, but the current double-T armature (Figure 4) still today stands for quality and reliability, innovation and technical leadership, efficient use of resources, simplification of live, significant benefit for the customer and suitable for series production. Since 2004, the logotype has been always used in combination with the symbol (Figure 5) (Bosch Worldwide, 2017).

1887 1907 1931

Figure 4 – Development of double-T armature symbol (Bosch Worldwide, 2017).

Figure 5 – Bosch symbol and logotype (Bosch Worldwide, 2017).

3.2 Bosch Car Multimedia Portugal

Bosch Portugal is represented by four divisions. Bosch Thermotechnology in Aveiro, Bosch Security Systems in Ovar, Bosch Car Multimedia in Braga and a sales office and Household Appliances division in Lisbon. These locations develop and manufacture a wide range of products, most of which are exported to international markets (Bosch Portugal, 2017).

Car Multimedia (CM) division in Portugal, headquartered in Braga, is the main plant in the CM division. Besides the building in Braga, CM is distributed by six other locations: Leonberg; Hildesheim; Hatvan; Wuhu; Suzhou; and Penang (Bosch Portugal, 2017).

CM develops smart integration for entertainment, navigation, telematics and driver assistance functions used in the original equipment business. CM core areas of competence include (Bosch Worldwide, 2017):

- highly integrated radio, entertainment, navigation and telematics systems;
- system integration of complex networked systems;
- devices and systems for commercial vehicles;
- premium instrument clusters, central and head-up displays;
- innovative tuner technology;
- repair of automotive electronic components.

While the vision of CM division is "Driving Convenience" which means "make mobility an exciting, enjoyable and safe experience by connecting passengers with the environment through multimedia and assistance solutions", the mission is to be "the leading supplier for infotainment, instrumentation, connected services and advanced driver assistance by understanding the vehicle as part of the internet and infrastructure for intermodal traveling and automated driving" (Bosch Worldwide, 2017).

Information, communication and entertainment in the vehicle environment play an integral role in automotive development. How the vehicle and driver interact with one another and by what means are decisive factors (Bosch Worldwide, 2017).

With more than forty five customers in the automotive market (Figure 6), CM division, in Braga, has certifications for quality, health, safety, energy and environment that include:

- ISO 9001 – Quality Management Systems;
- IATF 16949 – Quality Management Systems for Automotive Industry;
- ISO 14001 – Environmental Management Systems;
- ISO 5001 – Energy Management Systems;
- OHSAS 18001 – Occupational Health and Safety Management Systems.

Figure 6 – CM division automotive market customers.

The management of CM division, in Braga, is divided in commercial (BrgP/PC) and technical (BrgP/PT) areas that include different departments (Bosch GlobalNet, 2017). Commercial area is divided into nine distinct departments presented in Table 1.

Table 1 – BrgP Commercial area departments (Bosch GlobalNet, 2017).

AA-ES/MFR-PO	Automotive After Sales Electronic Service
BrgP/CFA	Controlling, Finance and Administration
BrgP/DBE	Communication and Operational Excellence
BrgP/HRL	Human Resources
BrgP/LOG	Plan Logistics
CI/CWR1-IB	IT Services
CM-MS/COR	Electronic Manufacturing Service Commercial
CP/PIR-IB	Purchasing
CP/PPM-Brg	Advanced Purchasing

Technical area is divided into twelve distinct departments presented in Table 2.

Table 2 – BrgP Technical area departments (Bosch GlobalNet, 2017).

BrgP/ENG	Development
BrgP/MFC	Manufacturing and Site Coordination
BrgP/MOE1	Minifactory 1 – Surface Mount Technology
BrgP/MOE2	Minifactory 2 – Assembly
BrgP/QMM	Quality Management
BrgP/MFE	Manufacturing Engineering
BrgP/HSE	Health Safety and Environment

CP/PQA-BrgP	Plan Quality Automotive
CP/TSC 2.7-EU	Technical Service Center for Plastics
CM-MS/TER	Electronic Manufacturing Service Technical
BrgP/PJ-I40	Project Industry 4.0
CM/PSO	Protection and Security Officer

Each department is subdivided into different sections. BrgP/MOE1 department, specifically, is subdivided into eight sections including: BrgP/M0E10; BrgP/M0E11; BrgP/M0E12; BrgP/M0E14; BrgP/M0E18; BrgP/M0E1-P; BrgP/M0E1-EWB; and CM/MFT3 (Bosch GlobalNet, 2017).

3.3 CM/MFT3 section

Manufacturing Technology 3 section (CM/MFT3) is worldwide responsible in the area of Printed Circuit Boards (PCB) assembly and interconnection technologies for (Bosch GlobalNet, 2017):

- process development, release and standardization;
- setup process and technology roadmaps together with business units development;
- definition of process quality standards for each process considering internal and external benchmark results;
- set up standard Process Failure Mode and Effect Analysis (P-FMEA) and Control Plans (CP) for all processes.

This section belongs to a centralized organization in Hildesheim and, according to the work developed, is organized into four different areas (Figure 7).

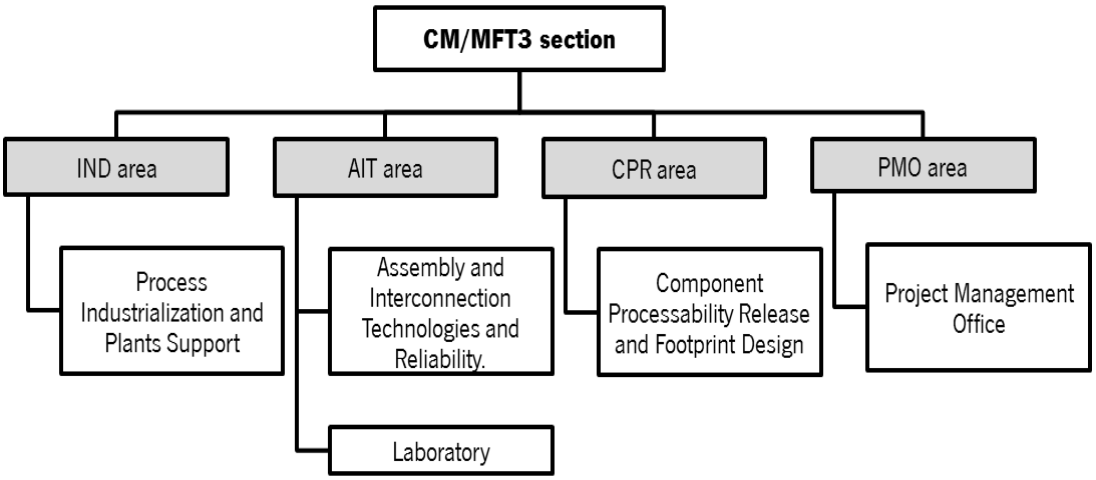


Figure 7 – Four areas of CM/MFT3 section.

All the activities carried out by CM/MFT3 section are related with PCB assembly. While 85% of the activities developed are operational, such as laboratory analysis, P-FMEAs, industrialization maturity

assessments (IMA), footprint design and component processability release (CPR), the 15% remaining are projects-related.

This master dissertation was developed in PMO area which is responsible for the integration of all areas in order to have all the work developed in the section connected, which makes essential the collaboration and good communication of all section's collaborators even if they work in separated areas. Apart from this, PMO area standardizes the project-related governance processes and facilitates the sharing of resources, methodologies, tools and techniques. This area contributes for functional knowledge and experience to the establishment and implementation of project management plan, feed project learning back into line functions and apply own capacity to the best benefit of the project in the most efficient way (Bosch, 2015).

In CM/MFT3 are developed two types of projects:

- Roadmap projects which are the ones that are planned and predicted since the year before;
- Non-roadmap projects that came up after the roadmap projects schedule plan was closed and are the ones that were not planned and will be carried out with less priority.

Roadmap projects can be AIT projects (which include PCB technology and components approval), IND projects and Innovation projects.

In addition, roadmap projects are distinguished by the category of the project: A, B, C or Non-project, that have different level of demand and, consequently, different level of effort from the project team, as shown in Table 3 (Bosch, 2017).

Technology Gates (TG) audits are conducted at the conclusion of each project phase, as a milestone point. TG audits are used as a quality tool and access the assurance of the production process development from the beginning to the end of the project (Bosch, 2016).

TG audits consist of audits based on a standard checklist with requirements that have to be accomplished at that specific phase of the project. All the TG audits are evaluated by an auditor from CM/MFI-Q department and if the requirements were achieved, the TG audit result is evaluated in green but if they were not, TG audit result is evaluated in yellow or even red. When evaluated in yellow, some improvements have to be done. When evaluated in red, some actions have to be performed in order to realign the projects targets with the actual results and the TG audit has to be repeated.

As Table 3 indicates, mandatory TG audits depend on project category, so it is not always necessary to do all the TG audits. The schedule of TG audits is fixed within the project schedule and is released by the sponsor.

Table 3 – Mandatory TG audits according to project category (Bosch, 2017).

Category	TG0	TG1	TG2	TG2a	TG3	TG4	TG5	Characteristics
A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	• Long-term impact; • New in new framework; • Multiple fields of expertise; • Highly complex structures; • Core competence.
B	Yes	Opt.	Yes	Opt.	Yes	Opt.	Yes	• Mid-term impact; • New within existing framework; • Several fields of expertise; • Key competence.
C	Yes	Opt.	Opt.	Opt.	Yes	Opt.	Yes	• Short-term impact; • None innovation; • One field of expertise (standard); • Standard competence.
Non-project	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.	• Minor impact; • Standard competence.

Legend: "Yes" – TG is mandatory in that category; "Opt." – TG is optional in that category.

Project preparation phase involves major work packages of the project that are (Bosch, 2016):

- determination of project category;
- signed project order with acceptance and release criteria and determination of the necessity of a steering committee;
- designation and compilation of the requirements from stakeholders;
- classification as core, key or standard technology;
- project management plan;
- sponsor's release regarding time schedule (including TG levels), resource plan and cost plan;
- project kick-off that is the first meeting and covers the project scope, project background, lessons learned and knowledge transfer from other projects, project objectives and assignment of the project roles to the members of the project team;
- definition of KPIs;
- escalation rules.

Apart from project preparation, a project involves some other phases. The flow of project development is illustrated in Figure 8. All these phases include (Bosch, 2016):

- concept evaluation phase – understand if all of the requirements from product development are known (including special characteristics);
- feasibility evaluation phase – clarification of technical feasibility;
- producibility evaluation phase – definition of process parameters like tolerances and clarification of transferability to series equipment;
- machinery and equipment (MAE) – preparation of requirements profile or specification sheet for third parties (requirements concerning technology, special functional requirements for the process, quality and scheduling);
- preparation for sample production phase – train of the required associates in sample construction;
- preparation for series production phase – production of sample parts according to current process instructions (A and B-Samples) and process rules for engineering (PRE) and production (PRP);
- process release phase – production of sample parts according to current process instructions (C-Samples), coordination to ensure secure ramp-up process which must fulfil series production requirements (including related documentation), proof of machine and process capability and the hand-over report.

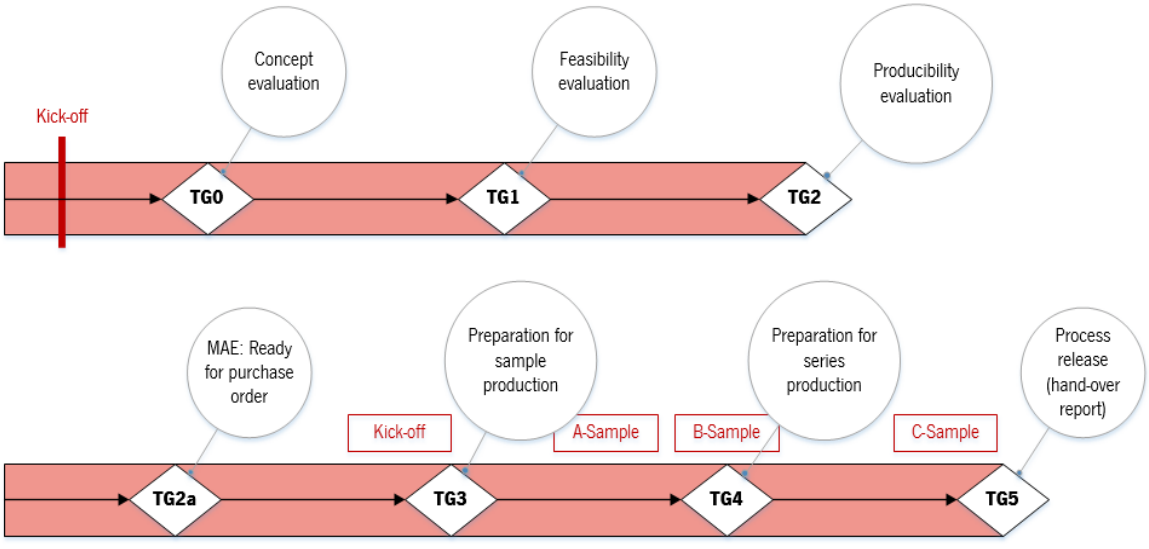


Figure 8 – Project life cycle (adapted from Bosch, 2016).

A requirement for CM/MFT3 is to have TG4 audit result before the C-Samples production, once the project requirements must be entirely attained and the process must be optimized when series production

start. If the achievement of project targets is at risk, then escalation to the sponsor has to be done immediately in order to define necessary additional actions without delay (Bosch, 2010).

4. PROCESSES MAPPING

In this chapter is described the actual situation of CM/MFT3 processes including how the processes are related. To enable the processes' formalization, the processes' descriptions, flowcharts and responsibilities are presented.

4.1 Analyzed processes and their relation

In ten years the growth of collaborators in CM/MFT3 section was of 900% (3 to 30 collaborators). Regarding to this growing, the implementation of quality methods and principles to provide a symbiosis of the section is necessary.

The section is divided into four areas (IND, AIT, CPR and PMO) with different processes and objectives. With the exception of production processes in charge of IND area, no other processes are standardized and formalized. Bearing this in mind, as there are a huge amount (around sixteen) of not formalized processes in the section, there was the necessity of choosing half of them to develop this master dissertation. The chosen processes were:

- relating to PMO area:
    - project management – roadmap project's activities to meet project requirements;
    - cost control – purchase requisition for goods/services for the section;
    - Process Failure Mode and Effect Analysis (P-FMEA) and Control Plan (CP) – consists of the analysis and identification of potential or known failure modes of the processes;
- relating to CPR area:
    - step stencil – process of variation of stencil thickness to control soldering paste volumes to solder components to PCB;
    - footprint design – process of arrangement of pads or through-holes used to physically attach and electrically connect components to PCB;
    - soldering thermal simulation – ensure that, the temperature distribution on the PCB, during soldering, is capable of providing a good solder junction on the PCB components;
    - component processability release (CPR) – PCB components approval process;
- laboratory analysis – AIT area process related with the conduction of the tests, mainly chemical, required by the plant.

These were the processes selected since it was agreed that processes of CPR and PMO areas should be the first to be described. PMO area is the one that governs project-related processes and costs that involve

all the areas. CPR area is related to PCB components which will incorporate new products and because of that it is an essential area of the section which needs to have systematic and controlled procedures. The number of laboratory analysis requests has been increasing year after year and because of that, it became urgent to define the process and the corresponding responsibilities. For this reason, this process was also selected, although it belongs to AIT area.

As a principle of quality management, processes approach supports that all of the processes should be interrelated and dependent on one another. This principle is verified in CM/MFT3 processes. Project management is the process that triggers almost all the other processes. Cost control process is associated with project management since it controls all the costs related with project activities, however it is also related with the laboratory analysis, step stencil and soldering thermal simulation because it controls all the purchases that are necessary to do in order to fulfil the processes needs like, for example, equipment or software. Laboratory is used to do all the tests required in the section and because of that, is related to footprint design when there is a necessity of components detailed information and to project management because processability and reliability tests validation required sectional cuts of mounted PCB which is an activity performed by the laboratory. Step stencil process is related not just with cost control, as already mentioned, but also with footprint design process that consists of a detailed description of PCB and it related-components and for that, an input necessary for footprint design process is given by step stencil process. Soldering thermal simulation process is related to cost control, as already mentioned, but also to footprint design for the same reason as step stencil process. CPR process is related with project management since it is an input for component-related projects. P-FMEA and CP is associated with project management since an output of an industrialization-related project is a P-FMEA and CP.

Figure 9 shows how the processes are related.

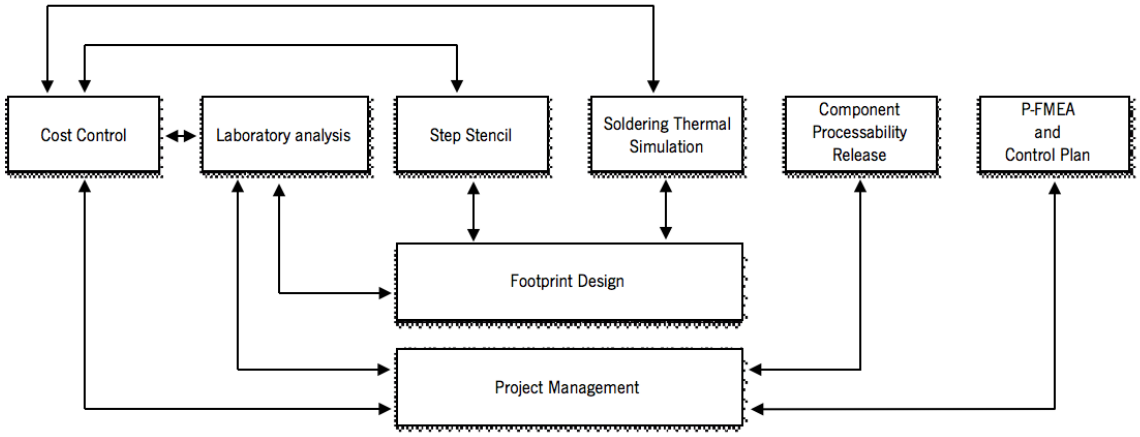


Figure 9 – CM/MFT3 processes' relation.

In order to collect information about the actual status of the section, a guideline was developed (Figure 10). This questionnaire was designed to identify the main activities of each process and collect detailed information behind processes execution. With its implementation, it was possible gather information and understand the section reality.

GUIDELINE FOR SEMI-STRUCTURED INTERVIEWS

- What is the process name?
- Who is the responsible for the process?
- What are the process objectives?
- What is the process trigger?
- What are the process inputs and outputs?
- What are the main activities of the process? By whom are performed?
    - These main activities, which are the most critical?
    - Are there any possible improvements for these activities?
- In the case of the same process be made by different people, are there any differences in the execution of the task? Or follows a standard execution?
- In the case of the same process be made by different people, can they access to the needed information? Where is the process-related information stored?

Figure 10 – Guideline used to collect information about the actual status of CM/MFT3 section.

The ISO 9001:2015 standard refers "the organization shall determine the processes needed for the quality management system (...) and assign the responsibilities and authorities for these processes".

Since the section's processes are not formalized and the persons responsible of processes are not defined, the questionnaire was addressed to those responsible of processes' activities.

Based on the inputs of the persons responsible of processes' activities, a flowchart for each process was elaborated. Flowchart was the tool chosen to represent the processes' flow. The principle of this tool is the effective and efficient transformation of input resources to process' output. Process flowcharting captures both the hierarchical nature and the sequence of a process (Kolarik, 1995).

Flowchart tool was supported by a RASIC matrix. RASIC matrix tool is used to document roles and responsibilities and helps to clarify communication channels for the defined activities. In the RASIC matrix, the following code identifies each participants' involvement (Baker, 2010):

- R – *responsible* for completing the work;
- A – authority to *approve* the work once it is completed;
- S – *support* in completing the work and help the person responsible;
- I – *informed* before, during, or at the conclusion of an activity and/or decision without playing an active role in executing the work;
- C – *consulted* to provide expert to technical information, advice or guidance without actively work on the task.

The RASIC matrix for each process was designed based on the inputs of the responsible of process activities.

After the conclusion of all the processes flowcharts and respective RASIC matrixes, and in order to fulfil the ISO 9001:2015 requirements, the head of section assigned a responsible for each process.

The next sections 4.2 to 4.9 present the processes description, processes flowchart and processes responsibilities through a RASIC matrix.

4.2 Project management

In CM/MFT3 there are activities that are handled e as projects due to their characteristics in terms of time, cost and resources. Project management is a section practice that involves the application of knowledge, skills, tools and techniques to assure that projects fulfil the agreed requirements.

When a request of a project is made to the section, depending on the project category (type B or C), only the mandatory TG audits (Table 3 of Chapter 3) are performed.

TG audits consist of quality audits based on a standard checklist with requirements that have to be accomplished at that specific phase of the project. All the TG audits are evaluated by an auditor from CM/MFI-Q department. For the different TG audits, different requirements are necessary:

- for the project first audit (TG0) to be performed, it is necessary the:

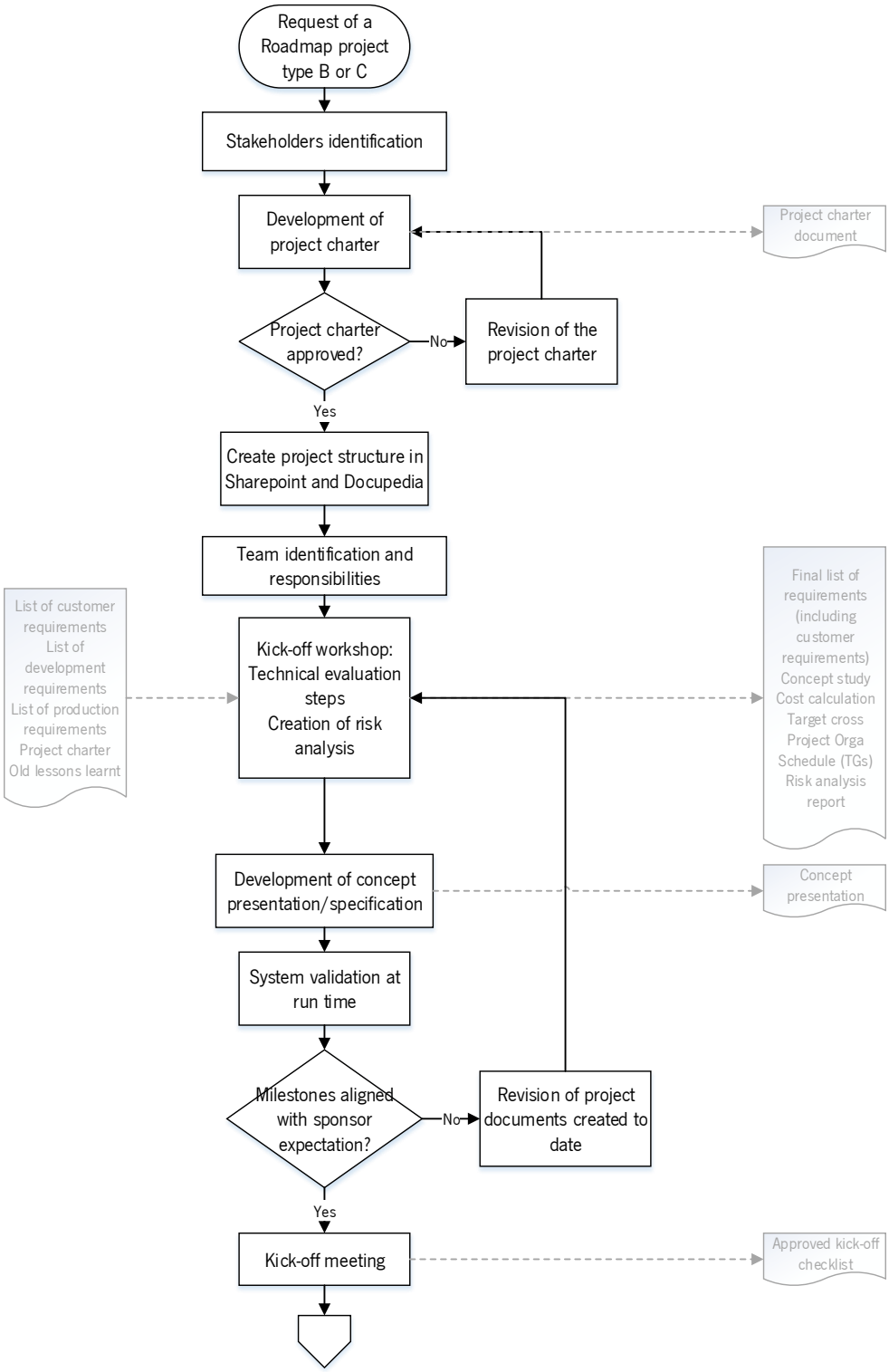
- formalization of the project commitment through “project charter” document which includes: sponsor and stakeholders identification; core team identification and responsibilities; project key dates, milestones and category; and budget;
- creation of a project structure in Sharepoint and Docupedia;
- documents creation like “Final list of requirements (including customer requirements)”; “Concept study”; “Cost calculation”; “Target cross”; “Project Orga”; “Schedule (TG audits included)”; and “Risk analysis”;
- development of concept presentation/specification which consists of the state of art and the current status about the technology itself likewise the challenges that the project involves;
- system validation at run time which consists of the validation of the modifications in the production line and the steps involved in the production process in question;
- creation and approval of the kick-off checklist which consists of the formalization of the project beginning.

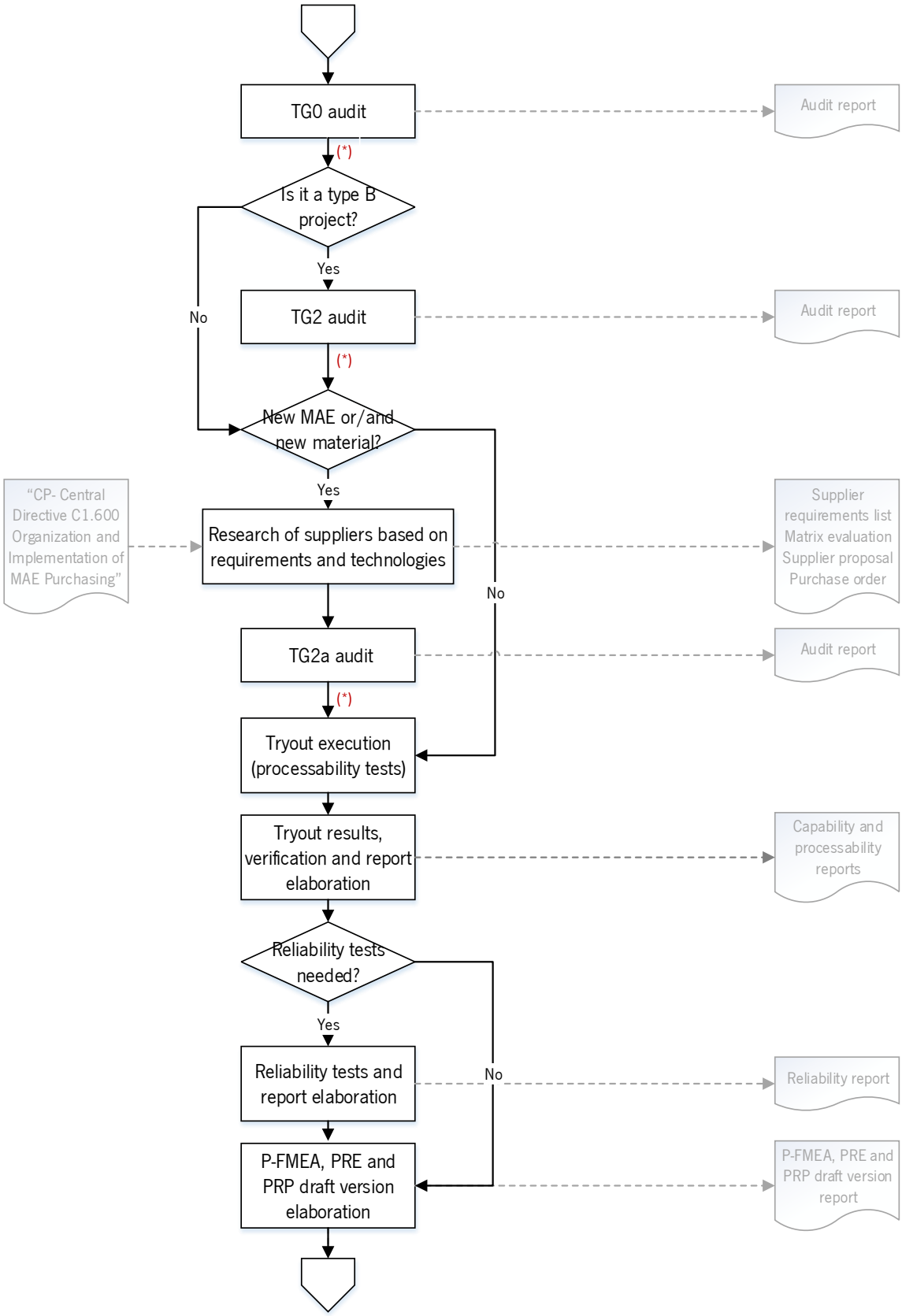
It is important to have in mind that, if in this stage, the milestones do not meet the sponsor expectations, some documents have to be revised (for example “Project charter”, “Risk analysis”, “Cost calculation” and “Concept study”).

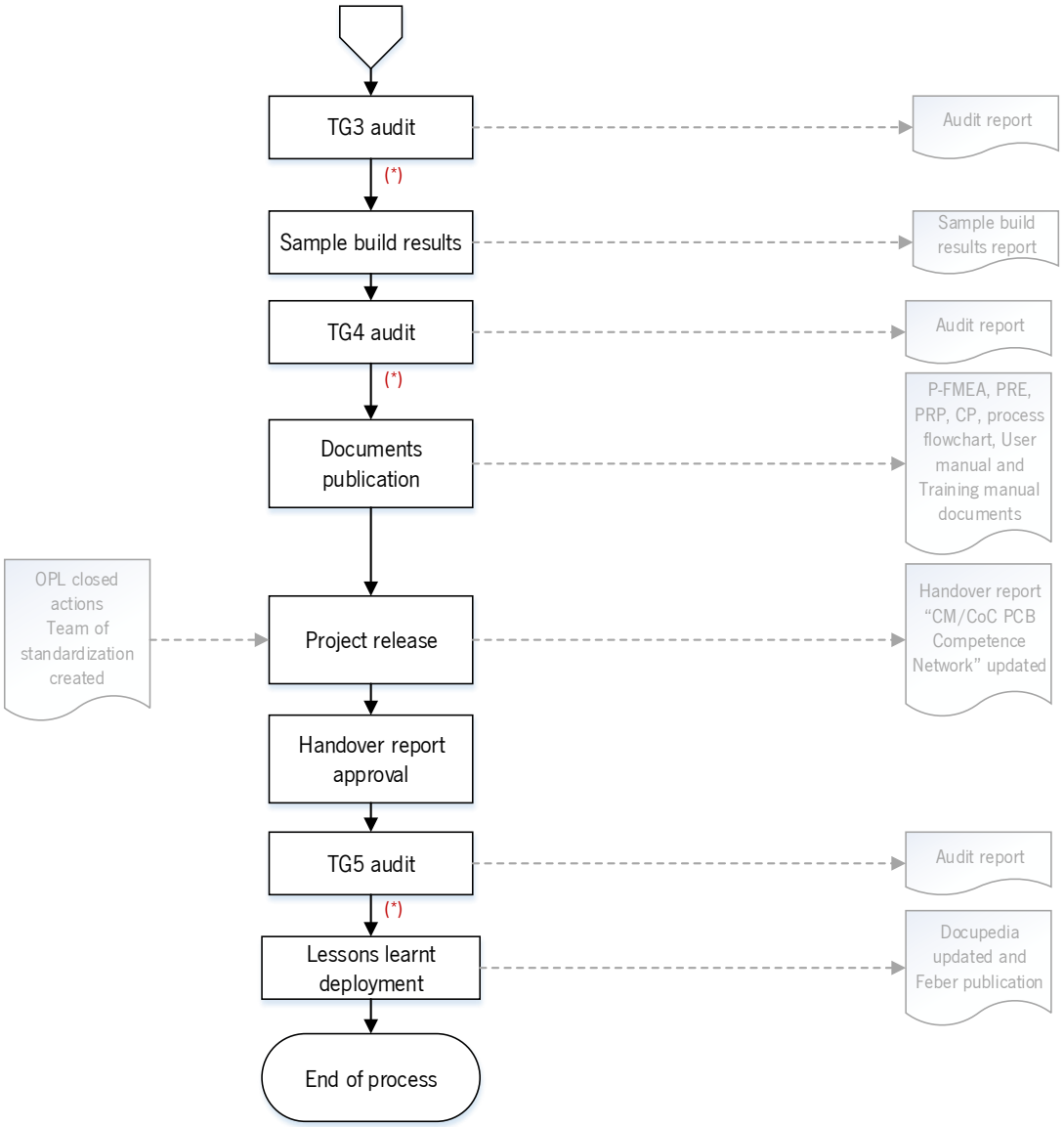
- for the projects type B, the TG2 audit is mandatory, and only in this case, the risk analysis (already elaborated) is evaluated;
- although not mandatory, TG2a audit is performed always that a project involves a purchase of a new machinery and equipment (MAE) and/or a new material qualification. It is considered that it is important to perform this audit in order to understand if there are not any error according to MAE acquisition and/or new material qualification process;
- for TG3 audit, components capability and processability tests have to be concluded and related reports released. If the project requires reliability tests, they have to be performed as well for this TG audit to be accomplished. Draft version documents like P-FMEA in the case of a new MAE, PRE and PRP have to be prepared and released;
- TG4 audit is not mandatory for type B and C projects, however as it is an important milestone since is through it that the time schedule of the project is crossed with the time schedule of the product release. Sample build results have to be achieved at this point;
- in general and regardless of project constraints, for TG5 audit realization, the handover report, which consists of the project final output, likewise PRE, PRP, P-FMEA (in the case of a new MAE)

and CP, process flowchart, user and training manuals have to be released and approved (final version).

The collection and deployment of project lessons learnt should be made as a continuous process. The process flowchart elaborated is presented in Figure 11.




TG0 audit
Audit report
(*)
Is it a type B project?
Yes
No
TG2 audit
Audit report
(*)
New MAE or/and new material?
Yes
No
"CP- Central Directive C1.600 Organization and Implementation of MAE Purchasing"
Research of suppliers based on requirements and technologies
Supplier requirements list
Matrix evaluation
Supplier proposal
Purchase order
TG2a audit
Audit report
(*)
Tryout execution (processability tests)
Tryout results, verification and report elaboration
Capability and processability reports
Reliability tests needed?
Yes
No
Reliability tests and report elaboration
Reliability report
P-FMEA, PRE and PRP draft version elaboration
P-FMEA, PRE and PRP draft version report



Legend:

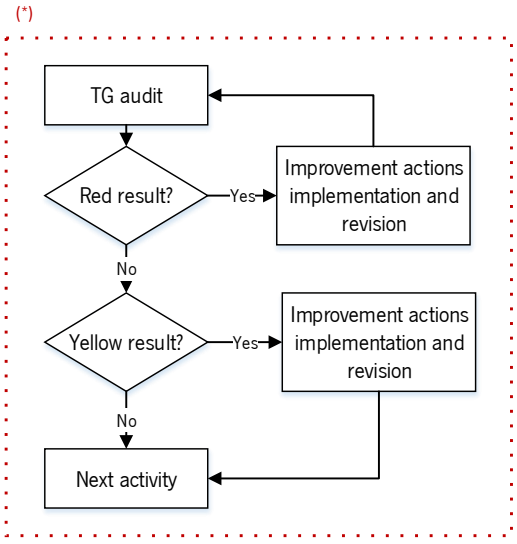


Figure 11 – Project management flowchart.

The responsible of the process is Jorge Coelho and a RASIC matrix (Table 4) was elaborated to define the persons responsible of the main activities.

Table 4 – RASIC matrix for project management.

	CM/MFT3 project manager	CM/MFT3 project responsible	CM/MFT3 head of section	CM/MFT3 section	CM/MFT department	Project sponsor	Key project stakeholders	CM/MFI-Q department	Organization CP	Plants
Stakeholders identification	R	R	R							
Project charter document	R	S, A	A		A	A	A			
Create project structure in Sharepoint and Docupedia	R	I	I	I						
Team identification and responsibilities	R		R							
Kick-off workshop and its reports related	R	R	S	S						
Development of concept presentation/specification and its report	I	R	I	S						
System validation at run time	I	R	I							
Revision of project documents created to date	R	R	S	S						
Kick-off meeting	R	S	S	S		S	S			
Kick-off checklist	R	A	A			A	I			
TG Audit								R		
Audit report	A	A	A		A	A		R		
Research of suppliers based on requirements and technologies and its documents related	I	R	S	S					R	
Tryout execution (processability tests)	I	R	I	S						
Tryout results and verification and report elaboration	I	R	I	S						

Reliability tests and report elaboration	I	R	I	S						
Sample build results and its report	I	R	I	S						
P-FMEA document	See the P-FMEA process RASIC matrix (Table 6).									
PRE and PRP documents	See "Approval and Information of Process Rules" document[1].									
CP document	See the P-FMEA process RASIC matrix (Table 6).									
Handover report	R	S	I, A	S	A	A				A
"CM/CoC PCB Competence Network" update	I, S		R	I						R
Lessons learnt deployment	R	R		S, I						

With all the process information collected and properly handled, a document was elaborated to enable the process formalization and standardization that will help the improvement of processes efficiency and effectiveness. The corresponding Bosch standard document involves the process description, the process flowchart and the persons responsible of process activities. In order to expose an example of the final result for one of the analyzed processes, in Annex I is presented the Bosch standard document related to this process.

4.3 Cost control

The cost control process main purpose is the purchase requisition of goods/services for the section.

The process starts with the necessity of a purchase. The materialization of the request requires the information of the supplier quotation and the quantity of material to be purchased. This information is handle by e-mail between the requester and the responsible of purchases with knowledge of purchase department.

After that, the first thing to be analyzed is if the ordering or purchase is associated with any project that has an own budget. Being associated with any project that has an own budget, is analyzed if it is an investment (purchase cost per item > 1000 €) or not. If it is not associated with any project that has an own budget, the Cost Center responsible has to approve the request for the ordering/purchase before be analyzed if it is an investment.

Being an investment, "Approval Investment" excel document is filled with the purchase information and once approved by PC/PT section, the purchase request is developed in SAP Software. If it is not an

[1] https://inside-ilm.bosch.com/irj/go/km/docs/room_extensions_rb/cm_stores/documents/workspaces/a07d92c9-6f75-2d10-8ca4-e6e556eb5410/Process%20Rules/Approval%20and%20information%20of%20process%20rules/PRE_PRP_Approval.xlsx

investment, SAP Software purchase request is automatically developed after the Cost Center responsible acceptance. One more approval process follows depending on the SAP Software purchase request parameters and purchase requisition (BANF) is created. If the BANF was successfully approved, purchase order number becomes available and the purchase order to the supplier is concluded.

When the order arrives to Bosch, it is delivered by logistic department to CM/MFT3 section and in the presence of an order that:

- is an investment, an inventory number has to be created by the controller of CM/MFT3;
- requires a calibration process, an Internal Number of Equipment Control (NICE) number has to be created by QMM7 section before it can be used.

Two flowcharts were elaborated, one related to the purchase requisition and the other related to the purchase reception.

The process flowchart related to the purchase requisition is presented in Figure 12.

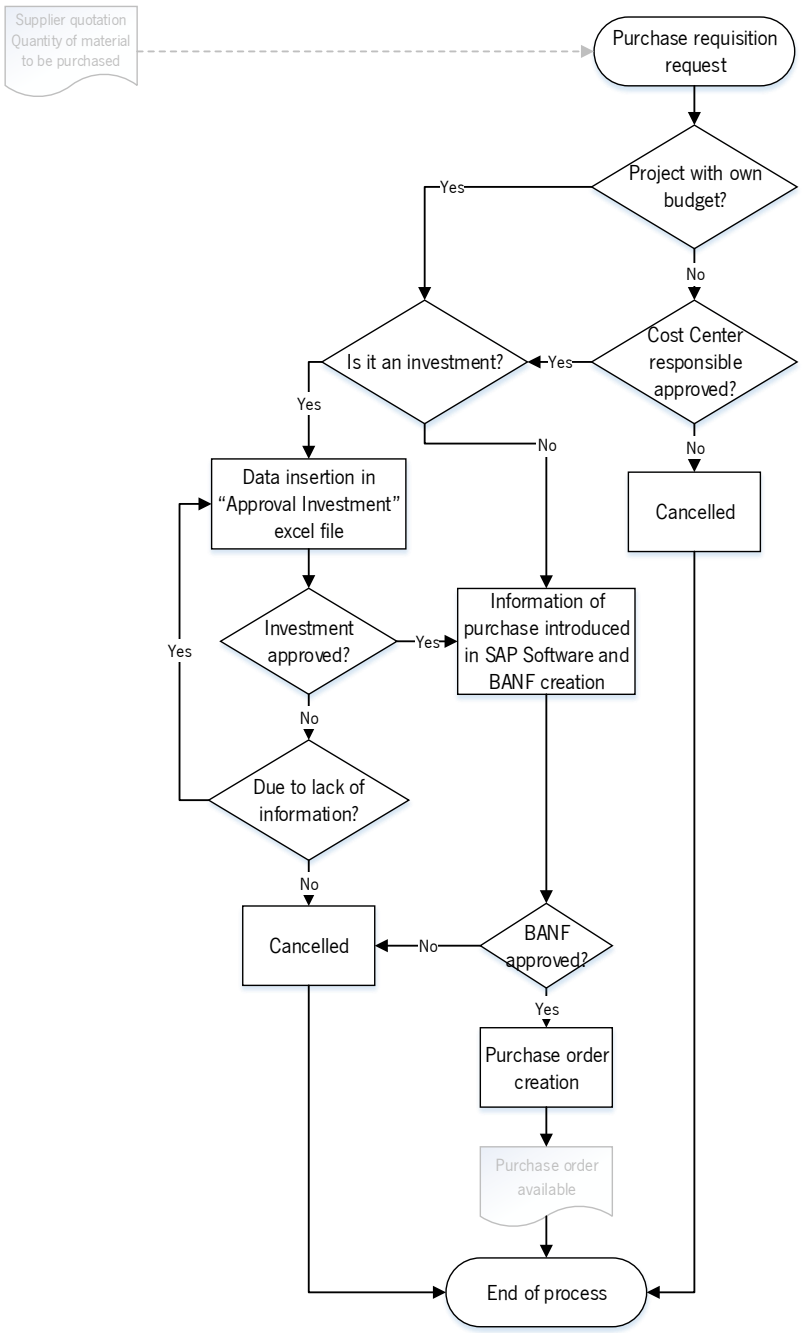


Figure 12 – Purchase requisition flowchart.

The process flowchart related to the purchase reception is presented in Figure 13.

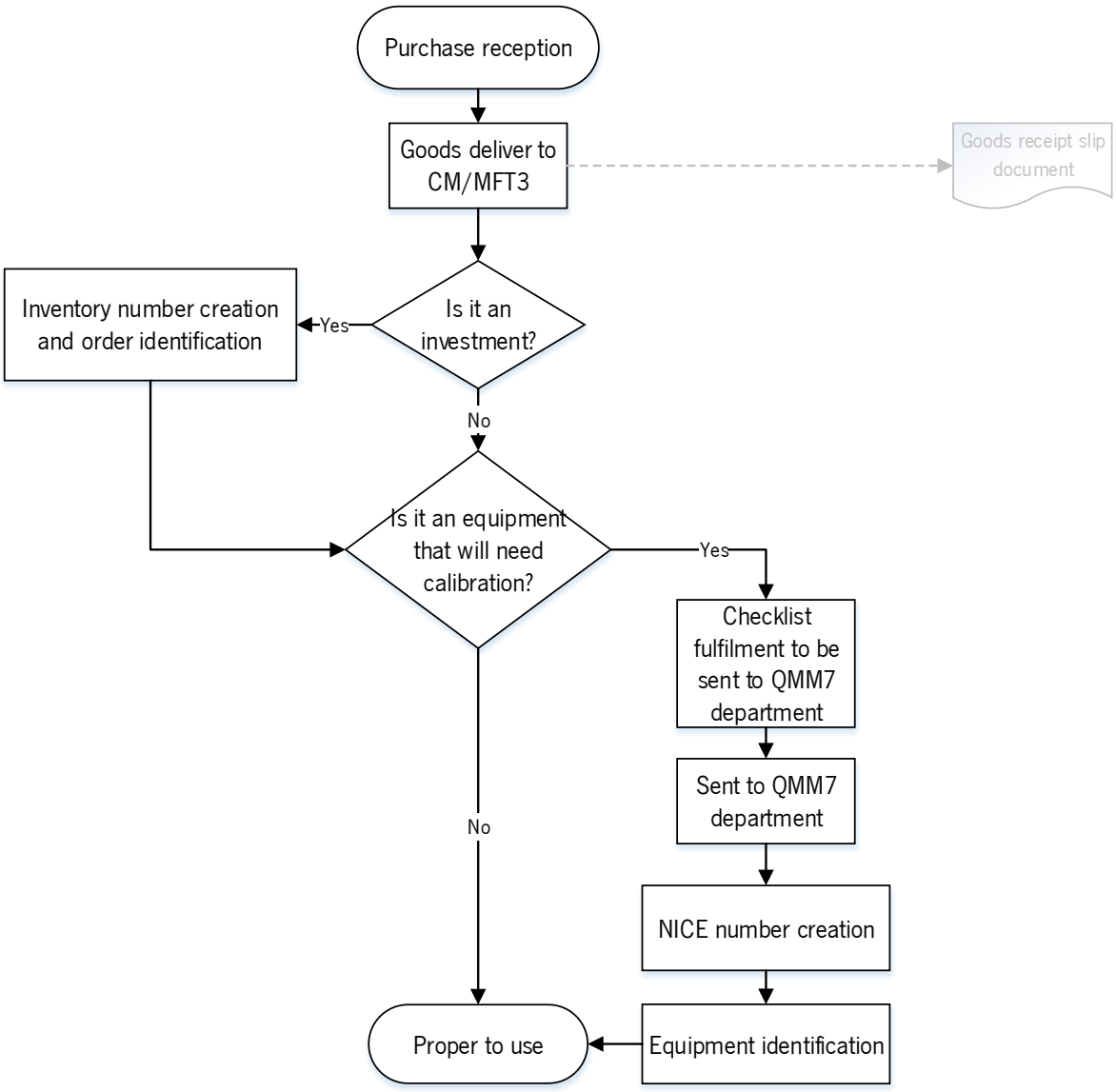


Figure 13 – Purchase reception flowchart.

The responsible of the process is Jorge Coelho and the RASIC matrix (Table 5) was elaborated, in accordance with the two flowcharts presented, to define the persons responsible of the activities.

Table 5 – RASIC matrix for cost control.

	CM/MFT3 requester	BANF creator	CM/MFT3 head of section	CM/MFT3 controller	Ordering center	CP/PIR332-EW, CP/PPM-BrgP sections	QMM7 section	Logistics incoming	CM/MFT3 GEIME manager	PC/PT section	Responsible for inventory in BrgP plant
Purchase requisition request	R	I									
Cost Center responsible approval	I	I	A								
Data insertion in "Approval Investment" excel file		R									
Investment approval	I	I								A	
Information of purchase introduced in SAP Software and BANF creation	I	R									
BANF approval (in SAP Software)		I	A	A							
Purchase cancellation (when applicable)	I	R	I	I							
Purchase order creation	I	I			R	R					
Goods deliver to CM/MFT3		I, S						R			
Inventory number creation and order identification	S	S									R
Checklist fulfilment to be sent to QMM department	S						I, S		R		
Sent to QMM7section							I		R		
NICE number creation							R		I		
Equipment identification	S								R		

Like in the previous case, a Bosch standard document was elaborated to formalize this process. The Bosch standard document consists of a process description, process flowchart and process roles and responsibilities.

4.4 Process Failure Mode and Effect Analysis and Control Plan

A Process Failure Mode and Effect Analysis (P-FMEA) document identifies the failure mode and effect analysis of production process that exist in the section and Control Plan (CP) is a document that controls the production process in order to avoid the possible failures described in the P-FMEA document.

More specifically, a P-FMEA is a disciplined analysis/method that identifies potential or known failure modes of each CM/MFT3 production process and provides follow-up and corrective actions during the processes lifetime.

As a result of the P-FMEA activity, a CP should be developed. The CP is a documented description of the systems and processes required for controlling the process under evaluation.

P-FMEA and CP development process initiates with a new request from the production process owner (CoC) whenever a new production process is planned.

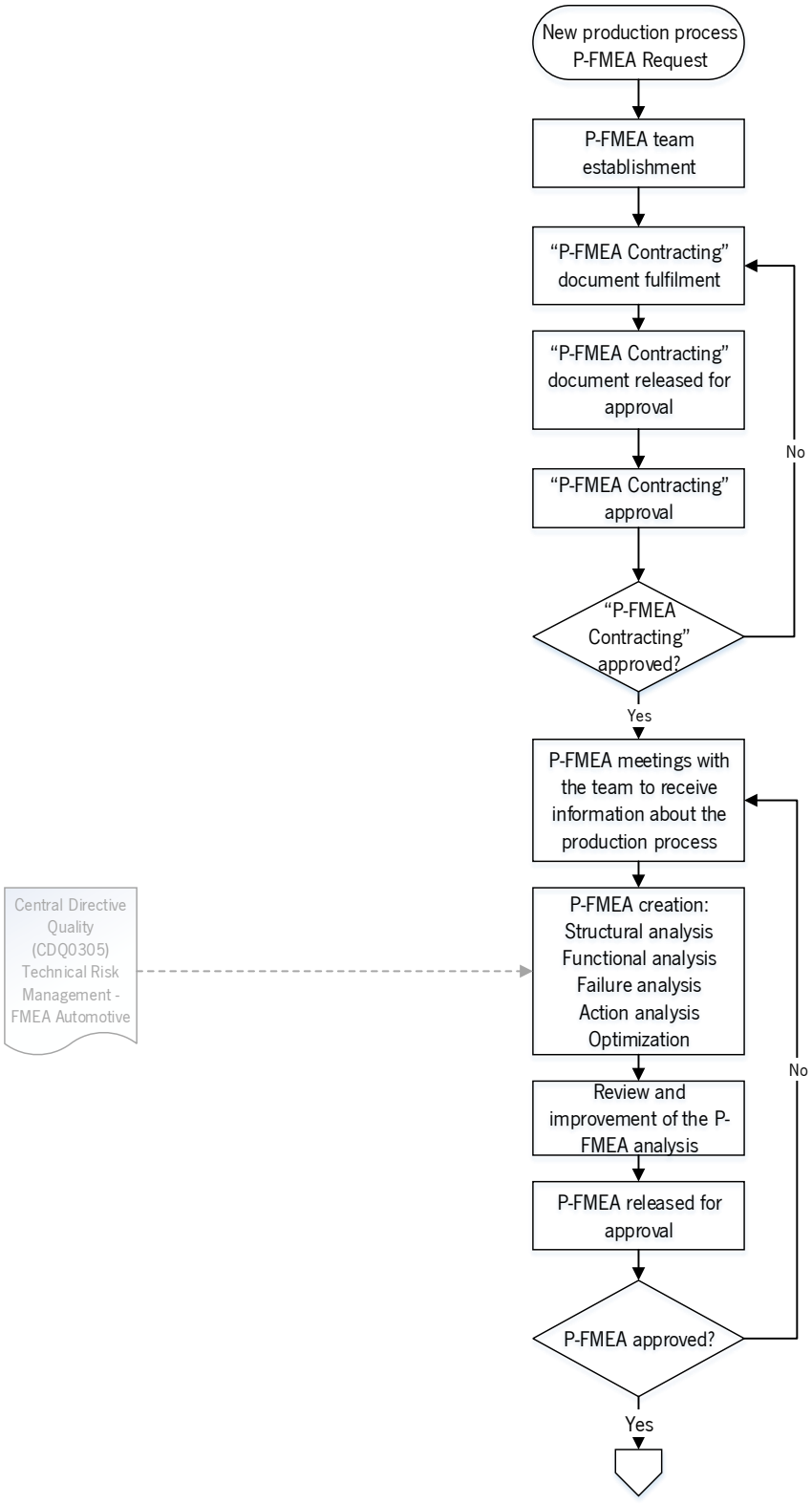
The P-FMEA formalization is made through the signing of "P-FMEA Contracting" which is a document that involves information about the team, description of team responsibilities, due dates for each steps and the production process in general. Since the "P-FMEA Contracting" document is approved and signed, meetings are performed to collect information about the production process and other pertinent information required for the P-FMEA elaboration.

P-FMEA moderator and his team, that are chosen based on "Central Directive Quality 305: Technical Risk Management - FMEA Automotive" document, start the P-FMEA preparation and when the study of the production process achieves an advanced stage, other meetings are performed to develop the five steps of the P-FMEA (structural analysis, functional analysis, failure analysis, action analysis and optimization). Before the approval, P-FMEA is reviewed and if there is any missing information, it is improved by the team.

When it comes to P-FMEA first edition, or in other words, to a new production process, the CP is only developed after the first production simulation since before it there is no information about the process characteristics, process specifications, inspection equipment, control methods and reaction plan.

Two different flowcharts were elaborated, one described below that considers the new P-MEA and CP requests and other that considers the P-FMEA and CP revisions.

In order to not cause delays in the project, the initial release of the new P-FMEA must be created at C-Sample and the initial release of the CP must be created only at D-Sample. The P-FMEA revision (after the end of the project) is initiated by the process manager with the support of the P-FMEA moderator. New P-FMEA creation process flowchart is presented in Figure 14.



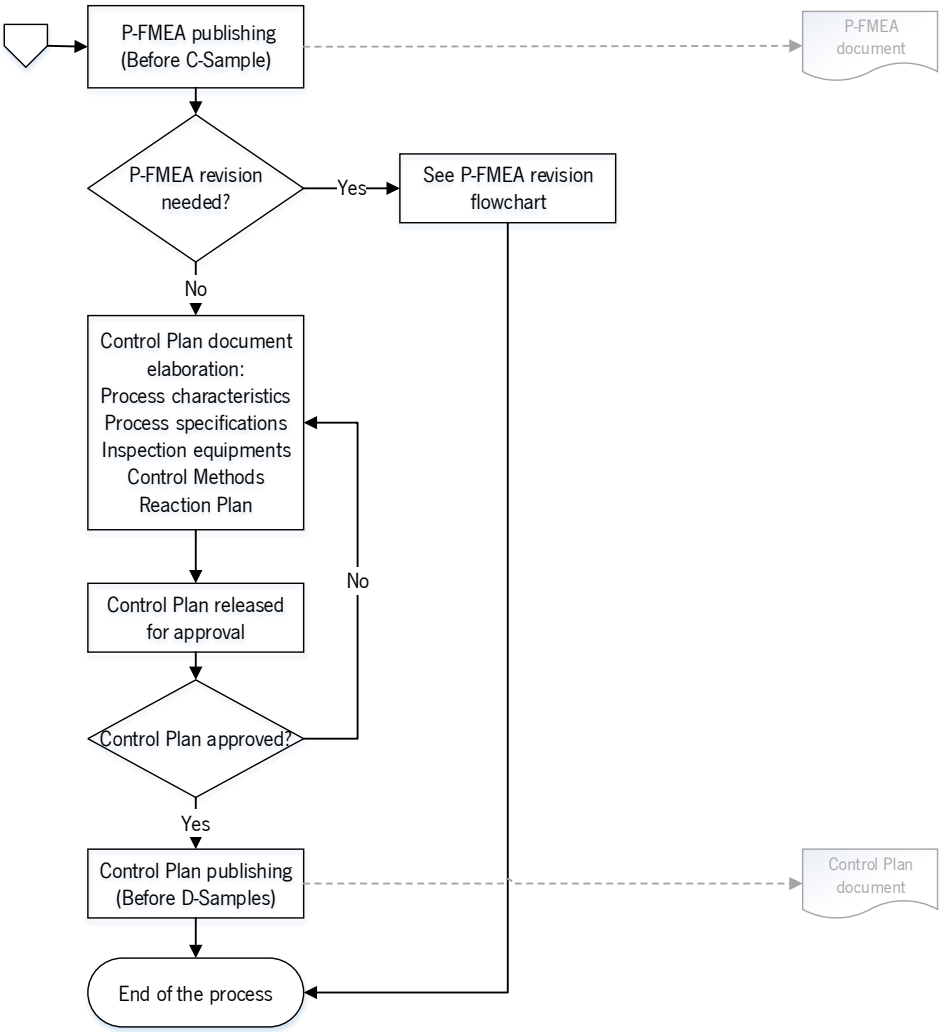


Figure 14 – New P-FMEA flowchart.

The responsible of the process is Natália Antunes and a RASIC matrix (Table 6) was elaborated in accordance with the flowchart presented and based on the process responsible inputs.

Table 6 – RASIC matrix for new P-FMEA elaboration.

	Process owner (CoC)	**P-FMEA moderator**	**P-FMEA team**	**CM/MFT3 head of section**	**P-FMEA coordinator**	**P-FMEA team**	**Head of department** (per plant)	**CM/MFI-Q department**
New production P-FMEA request	R	I						
"P-FMEA Contracting" document fulfilment	R	S	C					
"P-FMEA Contracting" document released for approval	A	R	I	A				
P-FMEA meetings	R	S	S					
P-FMEA creation	S	R	S					
Review and improvement of the P-FMEA analysis	S	R	S					
P-FMEA released for approval	A	R	A	A	I	A	A	A
P-FMEA publishing	I	R, I	I					
Decision of the necessity of a P-FMEA revision	R	I						
CP document elaboration	S	R	S					
CP publishing	I, A	R, I	I, A	A	I	A	A	A

A flowchart to describe the P-FMEA revision process was also elaborated and it is represented in Figure 15.

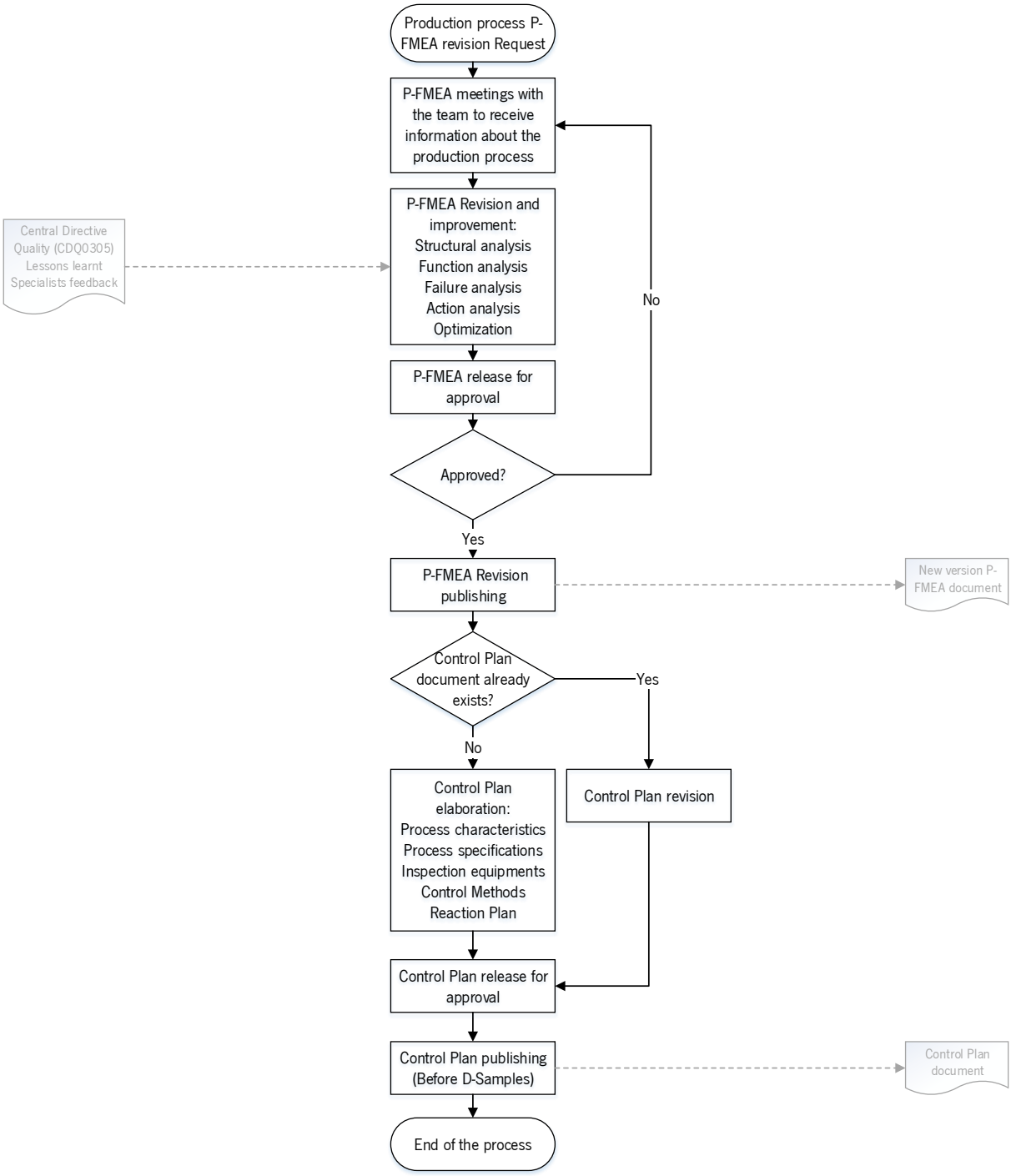


Figure 15 - P-FMEA revision flowchart.

For the P-FMEA revision a RASIC matrix was also elaborated (Table 7) to define the persons responsible of the activities of the process. The RASIC matrix filling was carried out with the contribution of Natália Antunes, the process responsible.

Table 7 – RASIC matrix for P-FMEA revision elaboration.

	Process owner (CoC)	**P-FMEA moderator**	**P-FMEA team**	**CM/MFT3 head of section**	**P-FMEA moderator and coordinator**	**P-FMEA team**	**Head of department** (per plant)	**CM/MFI-Q department**	**CM plant** (Specialist, Quality and Lessons Learnt representative)
Production P-FMEA revision request	R	I							R
P-FMEA meetings	R	S	S						
P-FMEA revision	S	R	S						
P-FMEA revision released for approval	A	R	A	A		A	A	A	
P-FMEA revision publishing	I	R	I	I		I	I	I	
CP document elaboration/revision	S	R	S						
CP released for approval (if elaborated)	A	R	A	A	(I)	A	A	A	
CP publishing	I	R	I	I		I	I	I	

The Bosch standard document to formalize this process, which consists of a process description, process flowchart and process roles and responsibilities, was elaborated.

4.5 Step stencil

Step stencil process main purpose is to regulate adequately the quantity of solder paste by adjusting the pad sizes. In other words, stepped stencils are necessary to optimally match the soldering paste volumes. To control paste deposits on PCBs (to solder components to the PCB), it is necessary to vary stencil thickness in specific areas to reduce volume (step down) or increase volume (step up) of solder paste (Lee, 2002).

Different designs have to be taken into account in the manufacture of stepped stencils. A standard step has 125 µm deep, however always that is mandatory a different depth in the stencil (≠ 125 µm), different stencil designs are required.

Whenever a new layout is released, either for a new product or for an update to the previous version, an automatic SAP Software notification is sent to CM/MFT3, and thus, the step stencil design procedure is triggered.

Following the layout release notification, a sequence of steps are executed like retrieving of gerber data from SAP Software, component list creation, step stencil design execution and output of step stencil design files (and support files). This procedure is in accordance with the document "Step Stencil Design Rules Ed.1.2".

When the process is complete, step design files are sent for verification and approval. Following the approval process, design files are then uploaded to SAP Software, making them available for stencil ordering teams of all CM plants.

Figure 16 represents the flow of the main activities of the process.

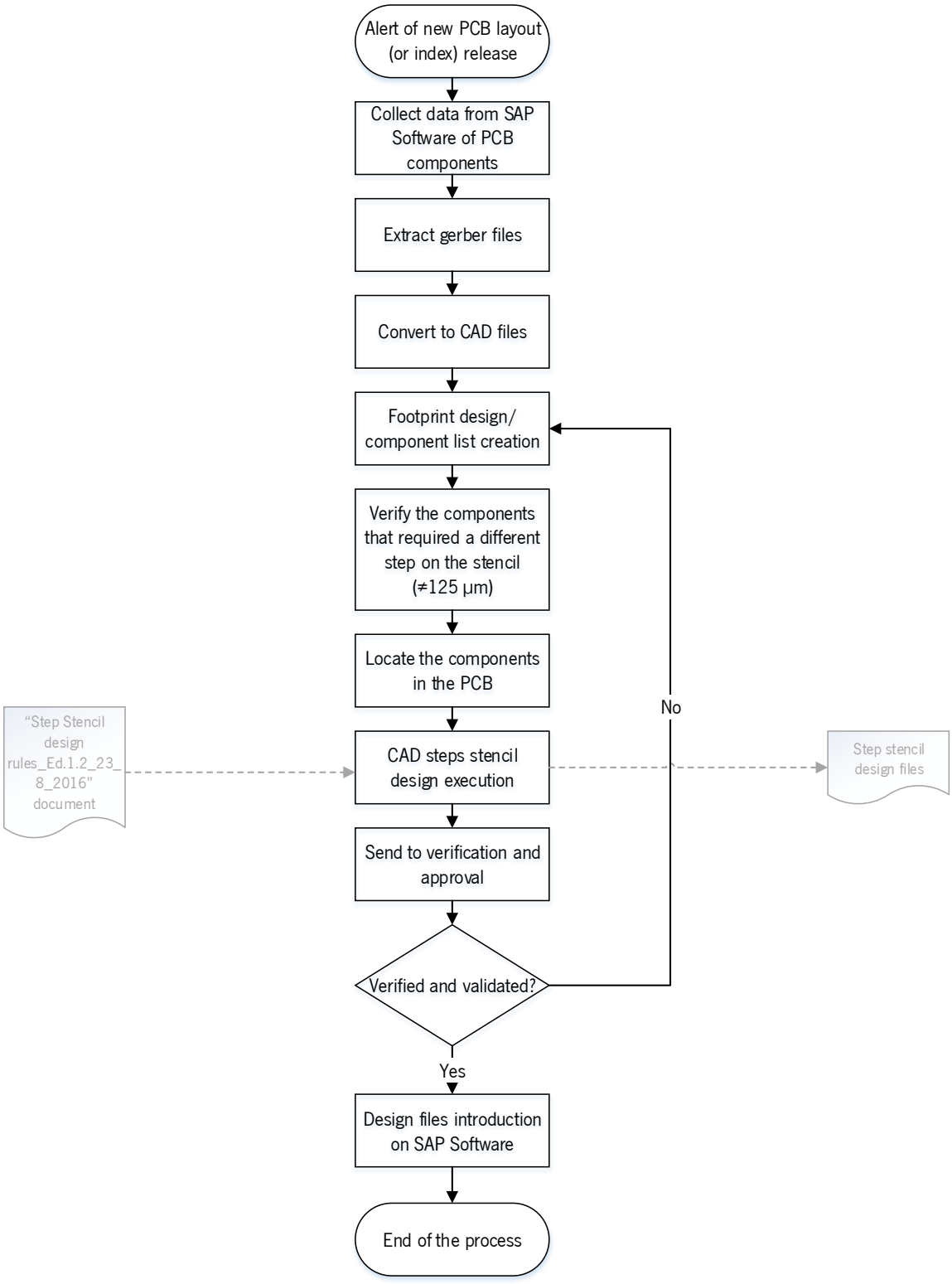


Figure 16 – Step stencil flowchart.

The responsible of the process is Luís Gomes. The RASIC matrix (Table 8) was elaborated in accordance with the process flowchart and the inputs of the process responsible.

Table 8 – RASIC matrix for step stencil.

	Step stencil expert	Step stencil designer
Alert of new PCB layout (or index) release	I	I
Collect data from SAP software	C	R
Extract gerber files and convert to CAD files	C	R
Footprint design/component list creation	C	R
Verify the components that required a different step on the stencil	C	R
Locate the components in the PCB	C	R
CAD steps stencil design execution	C	R
Send to verification and approval		R
Design files approval	A	
Design files introduction on SAP Software	R	

A Bosch standard document with all this information presented was elaborated to formalize the process.

4.6 Footprint design

Footprint design process main purpose is to design and supply a feasible and reliable footprint design to adequately and repeatedly solder a certain component to a PCB.

To correctly design a certain footprint, it is necessary to know the component to be used and which will be the soldering process. Then, it is possible to calculate and design the adequate Land Pattern[2] and stencil openings or selective nozzle (depending on the case) necessary to create a solder joint that allows the component to be correctly soldered into the PCB and withstand the required solicitations during product lifecycle.

When the request is made by PCB library team, the first parameter to analyze is if the component is a new technology/type or if it is an already approved one.

[2] Footprint design is constituted by a Land Pattern and a stencil.

If it is an approved technology/component type, it is necessary to collect data and analyze the supplier data sheet and PRE documents. Once all the necessary data is collected, the footprint design execution starts and when approved, the footprint design document is released and sent back to PCB library team.
If the component is a new technology/new type, and all the conditions to develop a project are met (technology/component is processable and is validated), a project is developed (according to Project Management flowchart), the footprint technology/component is tested and if it performed correctly, footprint design is executed. In the case that the conditions to develop a new project and a new technology/component are not available, footprint design is rejected.
Obviously that a footprint design that requires a new technology/component approval demands more time, workload and resources and it is why a new project is developed to validate it.
Since a footprint design is applied to a product, its behavior is checked and if some abnormality (for example solder defects or inspections defects) occurs and if that issue is due to some problem related to the footprint design or is a problem that can be fixed by the footprint design modification, then it is necessary to make a footprint design revision.
When an issue is reported, the first evaluation consists of verifying if the problem is solvable by a stencil modification only (meaning that no change is required in the Land Pattern). If that's the case, a Work Instruction (WI) where a new stencil design is defined is done and sent to production. If the result from this WI eliminates the issue, then the WI is transformed in a new footprint design index and the footprint design is updated.
Since a footprint design update is approved and released, the footprint design update document is published and sent back to PCB library team. However, if the footprint design cannot be improved and, thus, cannot be used, it is rejected. If the footprint design cannot be improved but can still be used, no updates are made to footprint design.
Two flowcharts were elaborated (Figures 17 and 18), one represents the new footprint design execution and the other represents the process of footprint design update execution.

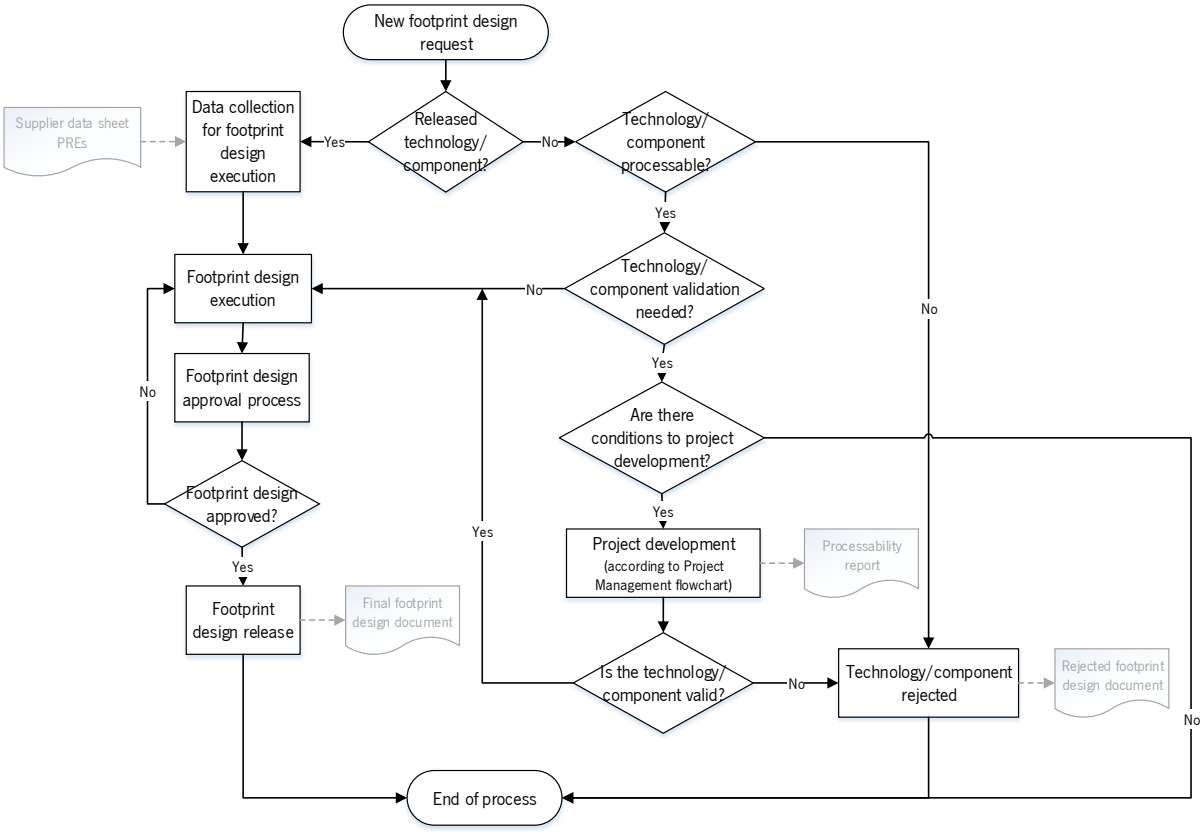


Figure 17 – New footprint design flowchart.

The head of section assigned Luís Gomes as the responsible of the process. The following RASIC matrix (Table 9) was elaborated to define the persons responsible for the activities of the process.

Table 9 – RASIC matrix for new footprint design.

	Footprint designer I	**Footprint designer II**	**Process owner** (CoC)	**CM/MFT3 head of section**	**Project manager**	**Product project manager**
New footprint design request	I	I				R
Technology/component release	R	R				
Decision of technology/component processability	I, R	I, S	S	S		
Decision of technology/component validation	I, R	I, S	S	S		
Analyze if there are conditions to a project development	I, R	I, S	S	S	S	
Project development	I, R	I, S	S	S	S	S
Technology/component rejection	I, R	I,S	S	S		
Data collection for footprint design execution	R	I, S				S
Footprint design execution	R	S				
Footprint design approval	R	A[3]	I, S	I, S		
Footprint design release	R	I				

A flowchart to describe the footprint design update process was elaborated and it is presented in the Figure 18.

[3] It is mandatory an approval confirmation by email.

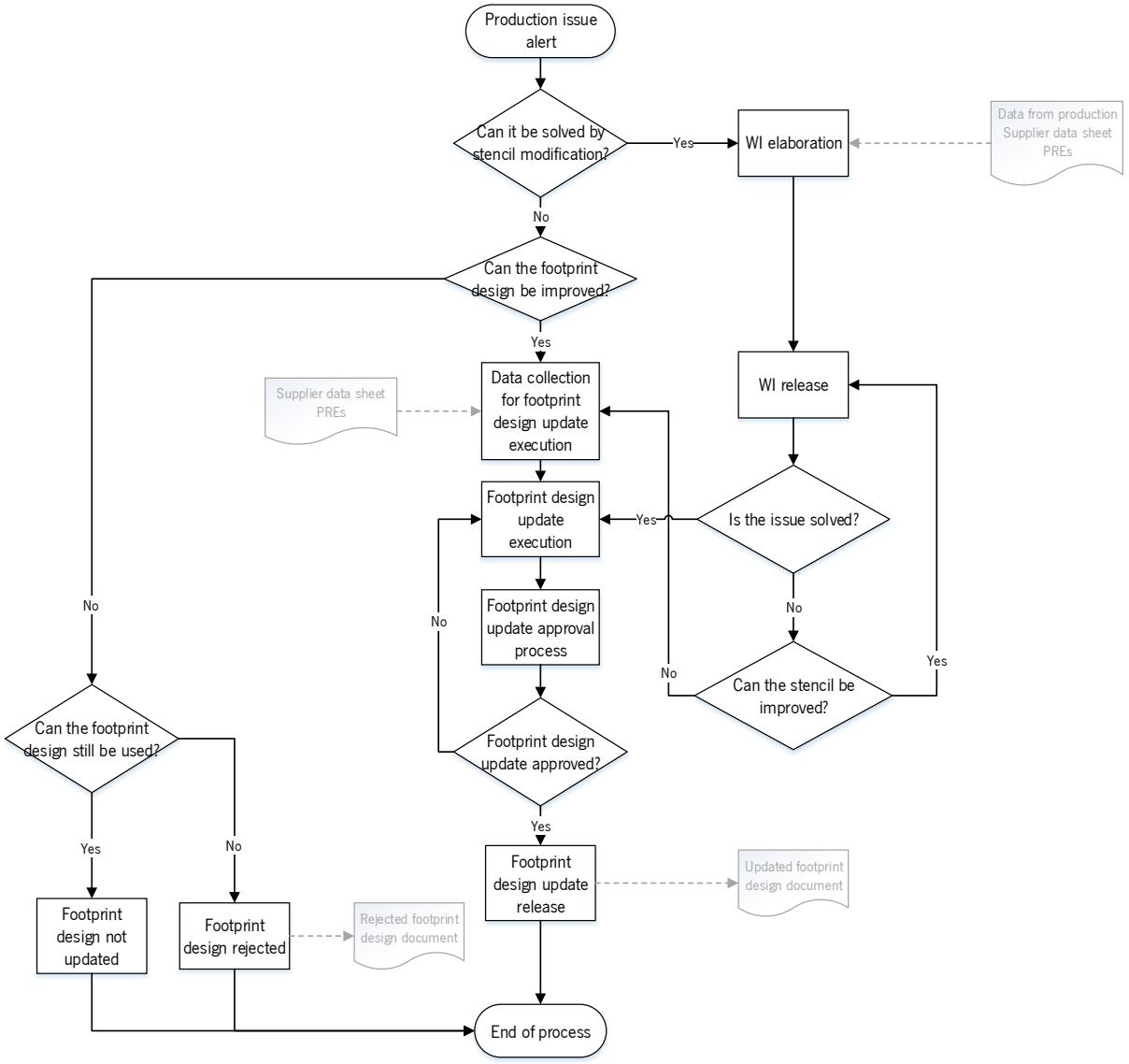


Figure 18 – Footprint design update flowchart.

For the footprint design update process, a RASIC matrix was also elaborated (Table 10).

Table 10 –RASIC matrix for footprint design update.

	Footprint designer I	**Footprint designer II**	**Process owner** (CoC)	**CM/MFT3 head of section**	**BrgP MOE12, PgP MOE18 MFT1, MFE departments**	**Product project manager**
Production issue alert	I	I			R	
Analyze if the issue can be solved by stencil modification	R	R				
WI elaboration	R	S			S	
WI release	R		A	I	A, I	
Analyze if the issue is solved	R	R	C		C	
Analyze if a design improvement is needed	R	R				
Data collection for footprint design execution	R	I, S				S
Footprint design execution	R	S				
Footprint design approval	R	A[4]	I, S	I, S		
Footprint design release	R	I				
Analyze if the footprint design can still be used (although cannot be improved)	R	R	S	S		
Footprint design rejection	R	I				

A Bosch standard document was elaborated to formalize this process.

4.7 Soldering thermal simulation

The purpose of thermal simulation is to ensure that the temperature distribution on the PCB, during reflow or selective/wave soldering, is capable of providing a good solder junction and does not introduce thermal stress on the PCB components. Once the simulation has been created and analyzed, a decision can be made on whether the PCB is processable from a thermal point of view (Gregory & Aldham, 2014). Thermal simulation starts with an automatic alert that is sent whenever a new PCB layout is released. A PCB layout that is not new but requires a new index (because relevant changes occurred) could also trigger the process.

[4] It is mandatory an approval confirmation by email.

When the alert is received and the request is not from IMA process, Layout Review process that consists of the filling of a document fields with the PCB technical characteristics, starts. One of the fields required is the TIF (Thermal Impact Factor) value that has to be calculated since it is the trigger to Thermal Simulation process. PCB TIF value is calculated to identify if the PCB is critical (TIF value > 5000 and/or exists a deviation from guideline PRE "Soldering Process E3-9-1-1") or not (TIF value < 5000 and none deviation from guideline PRE "Soldering Process E3-9-1-1"). Thermal impact analysis is executed to the complete PCB, according to "Soldering Process Thermal Simulation Work Instruction (Ed. 01.2)" document, in three cases: if the PCB is critical; if a previous simulation result was red; or in case of an IMA request.

6SigmaET is the tool used to execute the thermal analysis and when the process is completed, a report is released and the result information is introduced in SAP Software to further consultation. In the case of a red result ($\Delta T \geq 25\ ^{\circ}C$), CM/MFT3 tries to propose an improvement to the PCB since it has to suffer, mandatorily, an upgrading in order to be under the specifications for production.

If the PCB layout is not critical, thermal impact analysis does not need to be performed. The layout is released, validated and the information of PCB thermal behavior is introduced in SAP Software likewise in the Layout Review document.

The process flowchart elaborated is presented in Figure 19 and represents the process flow.

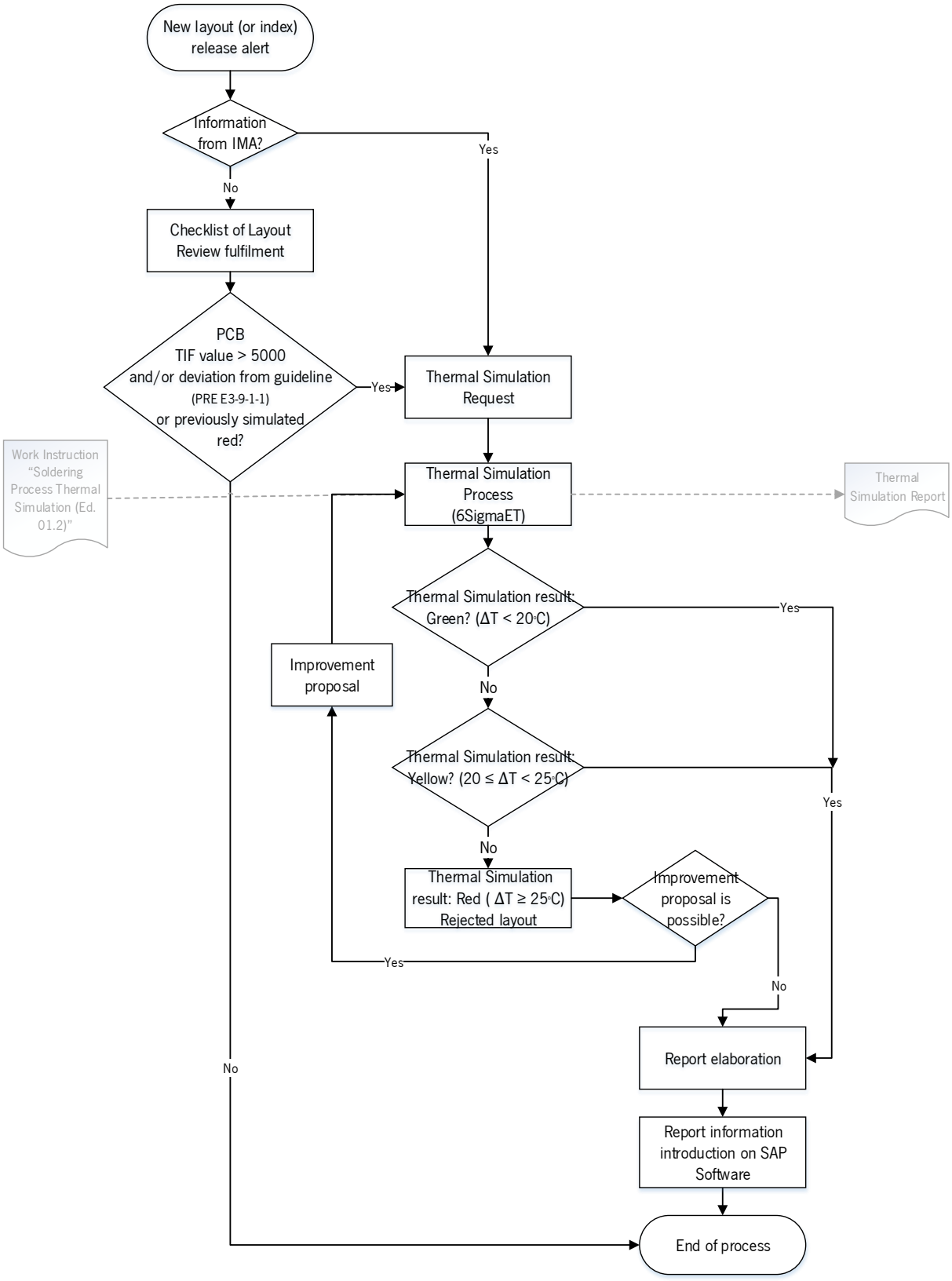


Figure 19 – Soldering thermal simulation flowchart.

The responsible of the process is Duarte Santos and a RASIC matrix (Table 11) was elaborated in accordance with process flowchart to define the persons responsible of the activities of the process.

Table 11 – RASIC matrix for soldering thermal simulation.

	IMA expert or layout review expert	**Thermal simulation expert**	**Layout review expert**	**Processes owner** (CoC)
New layout release alert			I	
Checklist of layout review fulfilment			R	
Simulation request	R	I		
Simulation process		R		
Improvement proposal		R		S, C
Report elaboration	I	R	I	
Report information introduction on SAP Software	I		R	

A Bosch standard document was elaborated to formalize the presented process.

4.8 Component processability release

Component processability release (CPR) is the PCB components approval process that consists of a checklist document fulfilment and verification tests.

A request is made and depending on the product state and the request owner (Development, QMS-P, CM-CI1/EHP4, BrgP-PPM or QMS-BP department), different types of responses can be given, although the checklist to be fulfilled is standard.

The checklist includes diverse requirements that the component has to fulfil to be approved. For the checklist filling, component documents from supplier are analyzed and, if necessary, discussed with the supplier. Processability tests are performed only if necessary.

If the checklist result is “component approved”, component processability release response is sent to the person that made the request. The response type is different according to the requester:

- if the request was made by Development department (as PLE request), an internal report with “PLE pre-assessment” is sent;

- if the request was made by QMS-P department (as PRP request), "PRP result status" is introduced in Bosch GlobalNet (BGN) portal as the response to the request;
- if the request is made by QMS-P, CM-CI/EHP4, BrgP-PPM or QMS-BP (as PRN, PR or EMS request respectively), a "PRD" report is sent.

If the checklist result is not acceptable to component approval, the component is rejected and the department that made the approval request is informed. If the component use is mandatory, a risk assessment proposal is made since the component, even rejected, has to be implemented and in this case, a concession is externally created. However, if the component use is not mandatory, a new request is made of an alternative component.

The flowchart elaborated is presented in Figure 20.

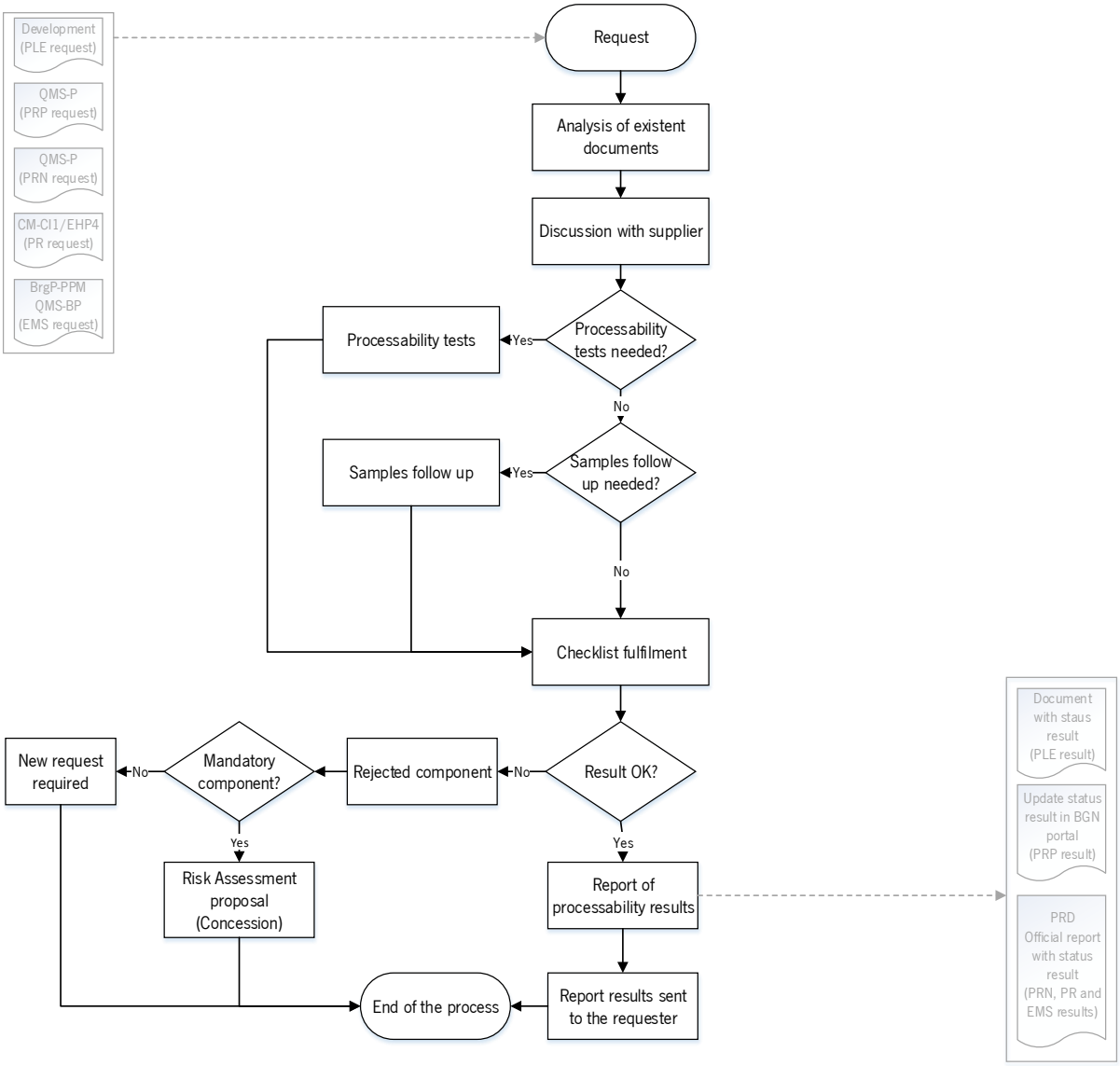


Figure 20 – Component processability release flowchart.

The responsible of the process is António Reis and a RASIC matrix (Table 12) was elaborated in accordance with process flowchart and based on the process responsible inputs.

Table 12 – RASIC matrix for component processability release.

	Team leader	**Active CPR**	**Passive CPR**	**Electromechanical CPR**	**Development, QMS-P, CM-CI1/EHP4, BrgP-PPM or QMS-BP departments**	**Supplier**	**Process owner** (CoC)	**PMO area**	**MOE1 or MOE2 departments**
Request	I	I	I	I	R				
Analysis of existent documents	C	R[5]	R[6]	R[7]					
Discussion with supplier	I	R[5]	R[6]	R[7]	I	S			
Processability tests	I	R[5]	R[6]	R[7]	I		A, C	I	A, I
Samples follow up	I	R[5]	R[6]	R[7]			A, C		
Checklist fulfilment	C	R[5]	R[6]	R[7]					
Risk Assessment proposal	C	R[5]	R[6]	R[7]	I		C		
Report of processability results	I	R[5]	R[6]	R[7]	I				

A Bosch standard document was elaborated to formalize the process.

4.9 Laboratory analysis

CM/MFT3 has a laboratory which is an investment of the section and is maintained by it. However, the analysis requests made (by email) to the laboratory are not only from CM/MFT3 section collaborators but from any section of the plant that requires a laboratory analysis like: scanning electron microscopy (SEM); energy dispersive X-ray spectroscopy (EDS); simultaneous thermal analysis (STA); stereo microscopy; optical microscopy; and wettability.

The main purpose of the laboratory is to characterize and analyze all the samples received and give response to all the requests in due time.

[5] Only if it is an active component;

[6] Only if it is a passive component;

[7] Only if it is an electrical component.

When the sample arrives to the laboratory, sample identification and characterization are made, mainly by photography. Later, the sample analysis is done and if an external service is needed, the sample is sent to an external entity (outside Bosch) and when it returns, analysis/consulting is completed.

A report (output) with the analysis results is released and sent (by email) to the person who made the request.

The process flowchart is presented in Figure 21.

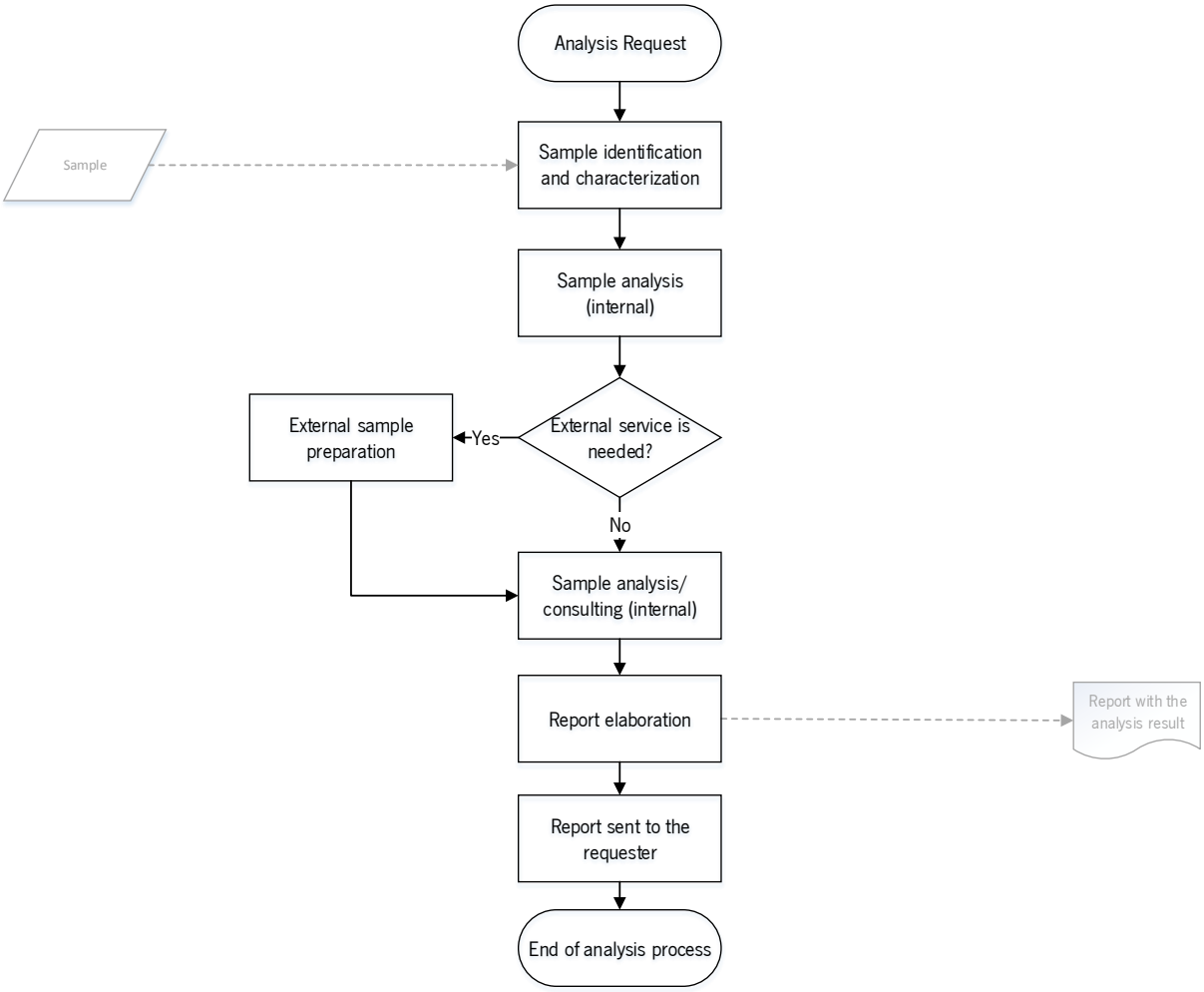


Figure 21 – Laboratory analysis flowchart.

Based on the contribution of the process responsible, Ricardo Alves, a RASIC matrix (Table 13) was elaborated.

Table 13 – RASIC matrix for laboratory analysis.

	Laboratory responsible	**Laboratory technician**	**Bosch customer**	**Process owner** (CoC)
Request	I	I	R	
Sample identification and characterization	S	R		C
Sample analysis	S	R		
External service needed	C, A			I, A
Sample analysis/ consulting	S	R		C
Report elaboration	R	R, S, A		
Report sent to requester	R	R	I	

Like in the previous cases, a Bosch standard document was elaborated to formalize this process.

The outputs of all of these described processes are, usually, inputs of another process of another section or department. To share internal data, Bosch company uses, mainly, SAP Software. This specific software provides the real time interaction through a common corporate database.

5. DEFINITION OF PROCESSES PERFORMANCE MEASURES

This chapter describes all the performance measures implemented and the new performance measures proposed to be implemented in CM/MFT3 section.

Thus, taking the processes' objectives into account, different performance measures were defined to quantify critical factors of each process in order to achieve the efficiency and effectiveness improvement. With a view to accomplishing this quantification, a performance measures template was created. The template is composed by the following fields that were based on Figure 2 presented in Chapter 2:

- performance measure name;
- performance measure type (lag or lead);
- formula;
- annual target;
- unit;
- frequency of measure;
- frequency of review;
- responsible for measurement;
- responsible for data;
- objective;
- observations;
- real value (year 2016);
- real value (year-to-date);
- final real value accumulated (year 2017);
- target deviation (year 2017).

There are some fields referred above that need a complementary explanation: some of the performance measures defined are lag or lead depending on whether they represent an effect or a cause, respectively; and the frequency of measurement varies from monthly to annually as the frequency of review.

The performance measures implemented for each process are presented in the next sections 5.1 to 5.8 and the template overview that was elaborated to organize the data and report the results is presented in Annexes II to IV. The processes measuring started at the beginning of the current year (January of 2017) and ended at the present day (beginning of July of 2017).

New proposals of performance measures to be implemented, in the future, in CM/MFT3 section are presented in the last section 5.9.

The objectives of the processes were the base of the performance measures definition. The objectives were set with the persons responsible of each process since they have a very good knowledge about the process and, thus, better perceptions about what it is relevant to be considered. Meetings were performed to discuss this topic and collect data.

5.1 Project management

Project management process is the one that involves almost all of the other processes and it main objectives are:

- prioritize roadmap projects;
- fulfil the project constraints (budget, resources, time and quality);
- perform TG4 audit before product C-Sample;
- have the proper and on time approved documentation to TG audits.

Considering these objectives, the following performance measures were established and implemented to their monitoring:

- *Roadmap Projects*;
- *Roadmap Versus Total of Projects*;
- *TG Audits Done*;
- *TG4's Alignment with Product C-Sample*;
- *Green TG Audits;*
- *Projects on Time.*

The performance measures description is presented in Tables 14 to 19.

Table 14 – *Roadmap Projects* performance measure.

Objective	Quantify the number of roadmap projects ongoing in the section.
Type	Lag
Formula	$Cumulative\ quantity\ of\ roadmap\ projects$
Annual Target	10
Unit	-
Frequency of measure	Monthly, since January of 2017
Frequency of review	Monthly, since January of 2017
Responsible for measurement	PMO area
Responsible for data	Head of section
Observations	Include AIT, IND and Innovation projects.

Table 15 – *Roadmap Versus Total of Projects* performance measure.

Objective	Quantify if the number of planned projects (roadmap projects) are higher than unplanned projects.
Type	Lead
Formula	$\frac{Quantity\ of\ roadmap\ projects}{Quantity\ of\ projects}$ x 100
Annual Target	100
Unit	%
Frequency of measure	Monthly, since January of 2017
Frequency of review	Monthly, since January of 2017
Responsible for measurement	PMO area
Responsible for data	Head of section
Observations	Unplanned projects are the ones that have a defined project charter with the corresponding costs and schedule, however were not planned and do not belong to roadmap project list.

Table 16 – *TG Audits Done* performance measure.

Objective	Compares the number of TGs done with the number of TGs planned to do.
Type	Lead
Formula	$\frac{Quantity\ of\ TGs\ done}{Quantity\ of\ TGs\ planned\ to\ do}$ x 100
Annual Target	100
Unit	%
Frequency of measure	Monthly, since January of 2017
Frequency of review	Monthly, since January of 2017
Responsible for measurement	PMO area
Responsible for data	Head of section
Observations	Mandatory TG audits depend on the project type B or C.

Table 17 – *TG4's Alignment with Product C-Sample* performance measure.

Objective	Quantify how many TG4 audits were timely performed.
Type	Lead
Formula	$\frac{Quantity\ of\ TG4\ done\ before\ product\ C-Sample}{Quantity\ of\ TG4\ done}$ x 100
Annual Target	100
Unit	%
Frequency of measure	Quarterly, since January of 2017
Frequency of review	Quarterly, since January of 2017
Responsible for measurement	PMO area
Responsible for data	Head of section
Observations	A project milestone is perform the TG4 audit before the product C-Sample.

Table 18 – *Green TG Audits* performance measure.

Objective	Measure the quality of the roadmap projects ongoing in the section.
Type	Lead
Formula	$\frac{Quantity\ of\ TGs\ done\ that\ were\ evaluated\ with\ green mark}{Quantity\ of\ TGs\ done}$ x 100
Annual Target	100
Unit	%
Frequency of measure	Quarterly, since January of 2017
Frequency of review	Quarterly, since January of 2017
Responsible for measurement	PMO area
Responsible for data	Head of section
Observations	If all the project requirements were achieved until the TG audit, the TG audit result is evaluated in green by the auditor.

Table 19 – *Projects on Time* performance measure.

Objective	Measure if the project activities are on time according to the schedule defined in the project charter.
Type	Lead
Formula	$\frac{Quantity\ of\ roadmap\ projects\ on\ time}{Quantity\ of\ roadmap\ projects}$ x 100
Annual Target	100
Unit	%
Frequency of measure	Quarterly, since January of 2017
Frequency of review	Quarterly, since January of 2017
Responsible for measurement	PMO area
Responsible for data	Head of section
Observations	-

One of the project constraints, resources, is not being monitored by the performance measures defined. The initial proposal was to calculate the rate of resources allocated (per project), however it was verified that only a few collaborators are permanently working in the projects from the beginning to conclusion of

the project. Usually, some collaborators give support in a particular phase of the project when necessary, and in these cases the participation of some collaborators is non-recurrent. Because of this fact, it is difficult to measure and monitor the time of intervention of the resources in the projects.

5.2 Cost control

The process' objective is to control the roadmap projects costs in order to never exceed the current year stipulated budget for all the roadmap projects ongoing in the section. Taking this objective into account, *Cost Plan Fulfilment* performance measure was defined and implemented to monitoring the roadmap projects-related costs. This performance measure description is presented in Table 20.

Table 20 – *Projects Cost Plan Fulfilment* performance measure.

Objective	Calculate the roadmap projects with own budget accumulated spending's.
Type	Lag
Formula	$\frac{Total\ spent}{Total\ available}$ x 100
Annual Target	100
Unit	%
Frequency of measure	Monthly, since January of 2017
Frequency of review	Monthly, since January of 2017
Responsible for measurement	PMO area
Responsible for data	Head of section
Observations	-

Apart from project-related purchases, PMO area is in charge to buy, among others, laboratory equipment, maintenance of equipment, as well as materials to the section in general. However, since the greater expenses are projects-related, there was established a performance measure to control only the costs associated with projects. An external controller (BrgP/CFA department) is in charge of the CM/MFT3 section overall costs control in terms of business planning operations, finance and accounting processes.

5.3 Process Failure Mode and Effect Analysis and Control Plan

P-FMEA and CP process' objectives are:

- quality, reliability, maintainability, cost and productivity satisfaction at optimum so the productive process can become more profitable;
- publication before product C-Sample.

Two performance measures were established to its monitoring.

- *P-FMEAs Planned to Publish;*
- *P-FMEAs Published on Time.*

It is perceptible that these two performance measures do not cover all of the objectives defined for the process. At this moment there is no way of monitoring if the P-FMEA and CP was a decisive tool regarding product process profitability. Questions like "Does the productive process become more profitable with the P-FMEA and CP publication?" or "Did the P-FMEA consultation enabled time or cost savings?" are very abstract and unquantifiable. However, these two performance measures implemented were considered a good starting point to monitoring the process.

The two performance measures are described in Tables 21 and 22.

Table 21 – *P-FMEAs Planned to Publish* performance measure.

Objective	Quantify the P-FMEAs planned to publish during 2017.
Type	Lag
Formula	$Cumulative\ quantity\ of\ new\ PFMEAs\ planned\ to\ publish$
Annual Target	1
Unit	-
Frequency of measure	Quarterly, since January of 2017
Frequency of review	Quarterly, since January of 2017
Responsible for measurement	PMO area
Responsible for data	Head of section
Observations	-

Table 22 – *P-FMEAs Published on Time* performance measure.

Objective	Quantify if always that a new process occur, a new P-FMEA was created and published on time (before product C-Sample).
Type	Lead
Formula	$\frac{Quantity\ of\ new\ PFMEAs\ published\ before\ C-Sample}{Quantity\ of\ PFMEAs\ published}$ x 100
Annual Target	100
Unit	%
Frequency of measure	Quarterly, since January of 2017
Frequency of review	Quarterly, since January of 2017
Responsible for measurement	PMO area
Responsible for data	Head of section
Observations	Only valid if the performance measure *P-FMEAs Planned to Publish* result is > 0.

5.4 Step stencil

The process main objective is to respond to the requests on time (within 72 working hours).

Taking this objective into account, two performance measures were considered:

- *Step Stencils Done;*
- *Step Stencils Done on Time*;

These performance measures description is presented in Tables 23 and 24.

Table 23 – *Step Stencils Done* performance measure.

Objective	Quantify the number of step stencil designs done.
Type	Lag
Formula	$Cumulative\ quantity\ of\ step\ stencil\ designs\ done$
Annual Target	320
Unit	-
Frequency of measure	Monthly, since January of 2017
Frequency of review	Monthly, since January of 2017
Responsible for measurement	CPR area
Responsible for data	Head of section
Observations	-

Table 24 – *Step Stencils Done on Time* performance measure.

Objective	Quantify the step stencils that were released on time (before 72 working hours).
Type	Lead
Formula	$\frac{Quantity\ of\ step\ stencils\ released\ on\ time}{Quantity\ of\ step\ stencils\ done}$ x 100
Annual Target	100
Unit	%
Frequency of measure	Monthly, since January of 2017
Frequency of review	Monthly, since January of 2017
Responsible for measurement	CPR area
Responsible for data	Head of section
Observations	Only valid if the performance measure *Step Stencils Done* result is > 0.

5.5 Footprint design

The process objective is to decrease the total time of footprint designs realization. Thus, it was attempted to implement in the section a software to monitor the time spent (per collaborator) in the activities performed. However, it was not successful because usually one activity is not performed from the

beginning to end without interruptions. Thus, the time spent per activity per collaborator was not possible to calculate properly.

Since it is difficult to calculate the time spent in footprint designs realization, *Footprint Designs Done* performance measure was established to its monitoring.

This performance measure description is presented in Table 25.

Table 25 – Footprint Designs Done performance measure.

Objective	Quantify the number of footprint designs done.
Type	Lag
Formula	$Cumulative\ quantity\ of\ new\ footprint\ designs\ done$
Annual Target	185
Unit	-
Frequency of measure	Monthly, since January of 2017
Frequency of review	Monthly, since January of 2017
Responsible for measurement	CPR area
Responsible for data	Head of section
Observations	Footprint designs update included.

5.6 Soldering thermal simulation

As the step stencil process, this process' objective is to respond to the requests on time (within 72 working hours).

According to these mentioned objectives, the following two performance measures were defined:

- *Simulations Done*;
- *Simulations Done on Time*.

The performance measures description is presented in Tables 26 and 27.

Table 26 – *Soldering Thermal Simulations Done* performance measure.

Objective	Quantify the number of soldering thermal simulations done.
Type	Lag
Formula	$Cumulative\ quantity\ of\ soldering\ thermal\ simulations\ done$
Annual Target	100
Unit	-
Frequency of measure	Monthly, since January of 2017
Frequency of review	Monthly, since January of 2017
Responsible for measurement	CPR area
Responsible for data	Head of section
Observations	-

Table 27 – *Soldering Thermal Simulations Done on Time* performance measure.

Objective	Quantify the soldering thermal simulations that were released on time (before 72 working hours).
Type	Lead
Formula	$\frac{Qualtity\ of\ simulations\ released\ on\ time}{Quantity\ of\ simulations\ done}$ x 100
Annual Target	100
Unit	%
Frequency of measure	Monthly, since January of 2017
Frequency of review	Monthly, since January of 2017
Responsible for measurement	CPR area
Responsible for data	Head of section
Observations	Only valid if the performance measure *Soldering Thermal Simulations Done* result is > 0.

5.7 Component processability release

The process objective is to decrease the total time of CPRs realization. According to this objective, and bearing in mind, as explained before in the footprint design process, the reasons why it is difficult to

calculate and estimate the time spent in a process realization, *CPRs Done* was the performance measure defined. This performance measure description is presented in Table 28.

Table 28 – *CPRs Done* performance measure.

Objective	Quantify the number of component processability releases done.
Type	Lag
Formula	$Cumulative\ quantity\ of\ CPRs\ released$
Annual Target	520
Unit	-
Frequency of measure	Monthly, since January of 2017
Frequency of review	Monthly, since January of 2017
Responsible for measurement	CPR area
Responsible for data	Head of section
Observations	CPR report is an approval component report which includes PRNs, PCNs, PRPs and PLEs.

5.8 Laboratory analysis

The objectives defined for the process are:

- increase the number of reports issued;
- increase the number of internal reports;
- increase the number of laboratory analysis.

Bearing in mind that the section invests in laboratory equipment and expertize, it is necessary monitor to understand if the equipment, mainly, are being profitable and for who (internal CM/MFT3 collaborators or external collaborators in the plant).

Considering these objectives, three performance measures were established to its monitoring:

- *Reports Released*;
- *External Versus Internal Reports Released*;
- *Laboratory Analysis Done*.

The related descriptions are presented in the following Tables 29 to 31.

Table 29 – *Reports Released* performance measure.

Objective	Quantify the number of reports released by the CM/MFT3 laboratory.
Type	Lag
Formula	$Cumulative\ quantity\ of\ reports\ released$
Annual Target	356
Unit	-
Frequency of measure	Monthly, since January of 2017
Frequency of review	Monthly, since January of 2017
Responsible for measurement	AIT area
Responsible for data	Head of section
Observations	-

Table 30 – *External Versus Internal Reports Released* performance measure.

Objective	Quantify the ratio between the number of internal reports and the total of reports issued.
Type	Lag
Formula	$\frac{Quantity\ of\ internal\ reports\ released}{Quantity\ of\ reports\ released}$ x 100
Annual Target	70
Unit	%
Frequency of measure	Monthly, since January of 2017
Frequency of review	Monthly, since January of 2017
Responsible for measurement	AIT area
Responsible for data	Head of section
Observations	Total of reports cover internal (for the CM/MFT3 section) and external reports (for all the plant, except CM/MFT3). Only valid if the performance measure *Reports Released* result is > 0.

Table 31 – *Laboratory Analysis Done* performance measure.

Objective	Quantify the number of analysis done, since one report required more than one analysis.
Type	Lag
Formula	$Cumulative\ quantity\ of\ analysis\ done$
Annual Target	24500
Unit	-
Frequency of measure	Monthly, since January of 2017
Frequency of review	Monthly, since January of 2017
Responsible for measurement	AIT area
Responsible for data	Head of section
Observations	Include the following analysis: photos; stereomicroscopy; sectional cuts; opticalmicroscopy; SEM; EDS; wettability; STA; environmental evaluation; and X-ray.

5.9 New proposals

As request of the head of section, it was given more emphasis to establish and implement lag performance measures. However, it was made a deployment in the CM/MFT3 section of the importance of the lead performance measures, since usually is too late to act when bad results of lag performance measures appear. It is the reason why having lead performance measures to monitor the processes of the section is important, allowing preventive actions to be taken timely. Because of their importance, some were already implemented in PMO area processes since it is the area that are interrelated with practically all of the others and, thus, was considered the starting point to implement lead performance measures in the section.

In this regard, in this section are proposed a few more lead performance measures to be implemented in CPR area processes and laboratory analysis process.

About step stencil process, the lead performance measure proposed to be implemented is *Quantity of Step Stencils Approved at First Time*. A step stencil approved at the first means that once submitted for approval, the step stencil was approved and no corrections will be needed. It is understood that any correction needed, after submitted for approval, causes a delay on the process. The purpose is, in the future, identify the causes of the corrections that are needed.

Table 32 describes the performance measure referred.

Table 32 – *Quantity of Step Stencils Approved at First Time* performance measure.

Objective	Quantify the number of step stencils approved at first time, without any corrections needed after submitted for approval.
Type	Lead
Formula	$\frac{Quantity\ of\ step\ stencils\ approved\ at\ first\ time}{Quantity\ of\ step\ stencils\ released}$ x 100
Annual Target	100
Unit	%
Frequency of measure	Monthly
Frequency of review	Monthly
Responsible for measurement	CPR area
Responsible for data	Head of section
Observations	-

Regarding to footprint design process, and bearing in mind the difficulties of implement a performance measure to monitor the time spent in a footprint release because the activity is not performed from the beginning to end without interruptions, the proposal is calculate the time of the delays of footprint designs released through *Delays of Footprint Designs Released* performance measure. The purpose is identify the cause of the delays.

Table 33 reports the description of the performance measure proposed.

Table 33 – *Delays of Footprint Designs Released* performance measure.

Objective	Quantify the average of delays of footprint designs release.
Type	Lead
Formula	$Cumulative\ time\ of\ delays\ of\ footprint\ designs\ released$
Annual Target	0
Unit	Hours
Frequency of measure	Monthly
Frequency of review	Monthly
Responsible for measurement	CPR area
Responsible for data	Head of section
Observations	Footprint designs are released on time before 48 working hours.

Soldering thermal simulation is a relatively recent process in the section. Regarding to this fact, the performance measures already implemented are, for the moment, sufficient to understand how the process is progressing.

Regarding to component processability release process, it is important calculate the fulfilment of requests made to the section. Thus, *CPR Requests* is the performance measure proposed to be implemented in the future. The main purpose is understand if the section has capacity to respond to all of the requests made.

Table 34 describes the performance measure proposed.

Table 34 – *CPR Requests* performance measure.

Objective	Understand if all the CPR requests have been answered.
Type	Lead
Formula	$\frac{Quantity\ of\ CPRs\ released}{Quantity\ of\ CPRs\ requests}$ x 100
Annual Target	100
Unit	%
Frequency of measure	Monthly
Frequency of review	Monthly
Responsible for measurement	CPR area
Responsible for data	Head of section
Observations	-

At last, regarding to laboratory analysis process, two lead performance measures are proposed to be implemented. One is related to the capacity of the laboratory equipment and the other if the reports were released on time. The first one has the main purpose of understand if the laboratory has the enough equipment capacity for answer to all the requests that are made. The second has the purpose of understand if all the requests are answered on time. The response time varies depending on the laboratory analysis requested and, thus, the responsible of the process must define the response time per laboratory analysis.

Tables 35 and 36 describe the performance measures: *Equipment Capacity* and *Reports Released on Time*.

Table 35 – *Equipment Capacity* performance measure.

Objective	Quantify the laboratory equipment profitability.
Type	Lead
Formula	$\frac{Time\ of\ eqipment\ utilization\ (hours)}{Time\ of\ equipment\ availability\ (hours)}$ x 100
Annual Target	100
Unit	%
Frequency of measure	Monthly
Frequency of review	Monthly
Responsible for measurement	AIT area
Responsible for data	Head of section
Observations	Per equipment.

Table 36 – *Reports Released on Time* performance measure.

Objective	Quantify if the reports were released on time.
Type	Lead
Formula	$\frac{Quantity\ of\ reports\ released\ on\ time}{Quantity\ of\ reports\ released}$ x 100
Annual Target	100
Unit	%
Frequency of measure	Monthly
Frequency of review	Monthly
Responsible for measurement	AIT area
Responsible for data	Head of section
Observations	The average time of response per laboratory analysis must be defined by the responsible of the process.

6. PROCESSES MONITORING: PERFORMANCE MEASURES IMPLEMENTATION

After the processes mapping and the establishment of processes objectives, performance measures were defined and implemented to monitor the critical factors of each process.

The section processes were not formalized and standardized and also, were not being recurrently monitored, nor existed an evaluation of their efficiency and effectiveness.

With the measurement and calculation of the performance measures, it was possible to evaluate the CM/MFT3 section success at reaching targets. In addition, the performance measures established and implemented:

- enable focus on critical aspects of outputs or outcomes;
- highlight the section strengths and weaknesses;
- help to identify and correct potential problems and issues;
- enable the control of decisions and reveal the gap between plan and execution;
- enable a review of the historical performance as well as set performance targets for the future;
- do not simply describe what has happened, but influence what will happen;
- provide information for taking decisions based on facts.

Performance measures results reflect the current state of processes situation. The data was collected during meetings with the responsible of each process, monthly or quarterly depending on the frequency of measurement.

For the performance measures that already existed, the targets were defined based on the values of the last year. For the new ones, the targets were projected by the head of section. Seven of the performance measures defined for the section are new and, therefore their targets were projected: *Step Stencils Done on Time; Soldering Thermal Simulations Done on Time; Roadmap Versus Total of Projects; TG Audits Done; TG4's Alignment with Product C-Sample; Green TG Audits; Projects on Time; P-FEMAs Planned to Publish; and P-FMEAs Published on Time.*

The ability of the collection of data was a parameter taken into account. Because of this fact, performance measures which not allow the ease of information collection for their calculation were not considered. It would be interesting to calculate the time spent, mainly, in the bottle neck activities performed by the section, however at this moment there is no effective way to obtain these values. For this reason, performance measures related to activities' time spent have not been taken into consideration.

An evaluation of the actual status of the section, in the two first quarters of the year, was made and the obtained results at the present day will be discussed. The processes measurement occur since January to June of 2017 and the results presented are related to the first semester of the year.

After the analysis of the performance measures results, presented in Annexes II to IV, it was possible to understand that, related to project management process, *Roadmap Projects* was one of the performance measures defined and quantifies the workload related to the current roadmap projects carried out in the section. The target (10 roadmap projects ongoing) has already been achieved (13 roadmap projects ongoing), however in this specific case, it is highly recommended that the target value do not be exceeded. *Roadmap Versus Total of Projects* is a performance measure important to understand if the projects carried out by the section were planned to be developed or not. Through the performance measure results it is clear that almost every projects were planned since, on average, 89% of the total projects ongoing in the section are roadmap projects.

TG Audits Done per project do not fulfil the target since, on average, only 51% of the TG audits planned to do, were effectively done. *TG4 Alignment with Product C-Sample* was other performance measure defined for the section and it is verified that, on average, only 67% of the audits performed occur before the product C-Sample release. For the project success, mainly in terms of time, it is important that the alignment between project TG4 audit and product C-Sample. *Green TG Audits* was a performance measure defined to characterize the quality of the project. The results of this two performance measures allow to understand that the TG audits have been done late but successfully evaluated by the auditor since all (100%) of the TG audits done so far were evaluated with green mark, which means that all the requirements established for the TG audits were accomplished.

The last performance measure defined for project management process was *Projects on Time.* According to the results, on average, only 58% of the projects ongoing in the section are on time. These delays are mainly related with the lack of availability of project teams since they have much activities in parallel and cannot devote entire time to the projects activities.

For cost control process monitoring, *Projects Cost Plan Fulfilment* was the performance measure defined. At the moment, only 22% of the budget allocated to the projects were already spent. This value allows conclude that has been made few purchases which is a consequence of the projects delays.

For the P-FMEA and CP process were defined two performance measures: *P-FEMAs Planned to Publish; and P-FMEAs Published on Time.* Through the results it is clear that the target was successfully achieved.

More performance measures were defined, these ones for CPR area. For the step stencil process, two performance measures named *Step Stencils Done* and *Step Stencils Done on Time* were established. The first one actual status is aligned with the target (43% of the target was already reached) and the average for the step stencils done on time is 78%. These results mean that the quantity of step stencils released is according to the expected and a high percentage of the releases was done on time.

For the soldering thermal simulation process two similar performance measures were defined, one related with the quantity of simulations done and other related with the process delays (*Soldering Thermal Simulations Done* and *Soldering Thermal Simulations Done on Time* respectively). For the first performance measure established, according to the actual status, the target will be extremely difficult to achieve, since at this point only 18% of the target was reached. Relating to the second one, the average is 74% of simulations released on time, being the target 100%. According to the results it is verified that in some months there was an intensification of workload, however in other months it was made an average of 1 simulation. This fact affects the percentage of delays since there are months with many requests in which is difficult to respond to all them on time and others with practically no requests.

For the footprint design process, *Footprint Designs Done* was the performance measure established and according to the actual status, it will be possible to achieve the target since, at the middle of the current year, already 56% of the target value was reached. The last performance measure defined for the CPR area was *CPRs Done*, which is related to CPR process. According to the actual status, the target will be achieved at the end of the year since 73% of the target was already achieved.

Regarding to the laboratory analysis process, the actual status of *Report Released* performance measure is green and therefore, it is on course to meet the target since 58% of the target value was already achieved. However, relating to the *Laboratory Analysis Done,* the target is unlikely to be met since only 28% of the target was fulfilled. The results of these two performance measures allow concluding that the reports released do not require many laboratory analysis as they required last year, since the targets were defined based on the last year results. However, it may also allow concluding that the counting of the analysis are not being made in the best way because, for example, a SEM photo (that can take 3 minutes) and a stereomicroscopy photo (that can take 1 hour) are being considered as having the same workload.

Regarding to *External Versus Internal Reports Released* the average value is 57% which do not fulfil the target established (75%). For the moment, the strategy of the laboratory is to answer, timely, to the section needs in terms of laboratory analysis requested.

After the implementation of the performance measures defined, it is important to note that they enabled the existence of an overview of the section actual status that reflects properly the performance of each process. However, it is important refer that the lead performance measures proposed are a very essential complement for the overview of the section processes and must be implemented.

7. CONCLUSIONS AND FUTURE WORK

The CM/MFT3 section is divided into four areas (IND, AIT, CPR and PMO) with different processes and objectives. With the exception of production processes in charge of IND area, no other processes were standardized and formalized. Regarding to this, there was no internal knowledge, neither a clear definition about the processes provided by the section.

With the description of the processes, flowcharts elaboration and responsibilities distributed, the processes were approved, formalized and standardized with an assigned owner, enabling:

- a clarity way to visualize the sequence of processes' steps;
- a standard way to communicate a specific process to those unfamiliar with it, such as new collaborators and/or outside auditors;
- a way to understand if the process is being done in the most efficient and effective manner possible in terms of cost and time;
- a formalized document with all the persons responsible for the main activities of each process;
- an easier definition of performance measures, mainly the leading ones.

Others difficulties found in CM/MFT3 section were the identification of the section needs, show the work done and understand if the requirements/milestones were fulfilled. All of these points were interpreted as section's needs that must be filled. Thus, according to the processes objectives, performance measures were defined to monitor the processes and overcome all these difficulties. Now, in CM/MFT3 section, there is:

- a guide to evaluate and obtain relevant results;
- a way to justify the needs/resources;
- a vision of section's work status;
- a reasoned way for the implementation of improvements.

To summarize, the objectives proposed for this master dissertation were achieved. Once developed and applied, brought the support documentation that the section needed.

The approach used to define the performance measures was also effective. The description of the processes was a crucial stage to understand in detail the processes and establish their objectives in order to be possible the properly definition of the performance measures.

It must, however, be borne in mind that there were some difficulties in the overall data collection, mainly related with the fact that the processes initially did not have any responsible assigned. Though even after the assignment of a responsible for each process, the lack of their availability, caused some unexpected delays.

The resistance to change, mainly related to the implementation of leading performance measures, was another difficulty felt. Thus, it was given priority to the implementation of lag performance measures and propose some lead ones to be implemented only when the lag ones become a standard practice in the CM/MFT3 section.

Continuous improvement should be focused on the improvements already done within this master dissertation in order to mature them. It is intended also that, through a transversal way, the processes formalization and standardization, as well as the performance measures definition should be cross-subsidized from the other two areas:

- AIT area processes should be formalized and should be chosen a responsible for each one. In this regard, performance measures should be established to its monitoring, as well as the data should be collected by the process responsible;
- although the IND area have already the production processes formalized and standardized, performance measures should be defined to be possible their monitoring.

From here, it is important to ensure that, if the processes eventually suffer any changes, the updates of the Bosch standard documents are made, as well as performed the continuous monitoring and feeding of the performance measures overview template.

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ANNEX I – BOSCH STANDARD DOCUMENT: PROJECT MANAGEMENT PROCESS

BOSCH

From	Our Reference	Tel	Braga
CM/MFT3	Mariana Monteiro	+351(253)30-6100	30 July 2017

Report

Issue Project management
Topic **Process summary**
Description Process description, flowchart and responsibilities

Process description

In CM/MFT3 there are activities that are handle as projects due to their characteristics in terms of time, cost and resources. Project management is a section practice that involves the application of knowledge, skills, tools and techniques to assure that projects fulfil the agreed requirements.

When a request of a project is made to the section, depending on the project category (type B or C), only the mandatory TG audits (Table 1) are performed.

TG audits consist of audits based on a standard checklist with requirements that have to be accomplish at that specific phase of the project. All the TG audits are evaluated by an auditor from CM/MFI-Q department and if the requirements were achieve, the TG audit is evaluated in green but if they were not, TG audit is evaluated in yellow or even red. When evaluated in yellow, some improvements have to be done. When evaluated in red, some actions have to be performed in order to realign the projects targets with the actual results and the TG audit has to be repeated.

Table 1 - Mandatory TGs according to project category.

		Mandatory TGs					
		TG0	TG2	TG2a	TG3	TG4	TG5
Project category	B	X	X		X		X
	C	X			X		X

For the different TG audits, different requirements are necessary:

- for the project first audit (TG0) to be performed, it is necessary the:
  - formalization of the project commitment through "project charter" document which includes: sponsor and stakeholders identification; core team identification and responsibilities; project key dates, milestones and category; and budget;
  - creation of a project structure in Sharepoint and Docupedia;

- documents creation like "Final list of requirements (including customer requirements)";"Concept study"; "Cost calculation"; "Target cross"; "Project Orga"; "Schedule (TG audits included)"; and "Risk analysis";
- development of concept presentation/specification which consists of the state of art and the current status about the technology itself likewise the challenges that the project involves;
- system validation at run time which consists of the validation of the modifications in the production line and the steps involved in the production process in question;
- creation and approval the kick-off checklist which consists of the formalization of the project beginning.

It is important have in mind that, if in this stage, the milestones do not meet the sponsor expectations, some documents have to be revised (for example: "Project charter", "Risk analysis", "Cost calculation" and "Concept study").

- for the projects type B, the TG2 audit is mandatory, and only in this case, the risk analysis (already elaborated) is evaluated;
- although not mandatory, aTG2a audit is performed always that a project involves a purchase of a new machinery and equipment (MAE) or/and a new material qualification. It is considered that it is important to perform this audit in order to understand if there are not any error according to MAE acquisition or new material qualification process;
- for TG3 audit, components capability and processability tests have to be concluded and related reports released. If the project requires reliability tests, they have to be performed as well for this TG audit be accomplished. Draft version documents like Process-Failure Mode and Effect Analysis (P-FMEA) in the case of a new MAE, Process Rules Engineering (PRE) and Process Rules for Production (PRP) have to be prepared and released;
- TG4 audit it is not mandatory for type B and C projects, however as it is an important milestone since is through it that the time schedule of the project is crossed with the time schedule of the product release. Sample build results have to be achieved at this point;
- in general and regardless of project constraints, for TG5 audit realization, the handover report, which consists of the project final output, likewise PRE, PRP, P-FMEA (in the case of a new MAE) and Control Plan (CP), process flowchart, User and training manuals have to be released and approved (final version).

From
CM/MFT3

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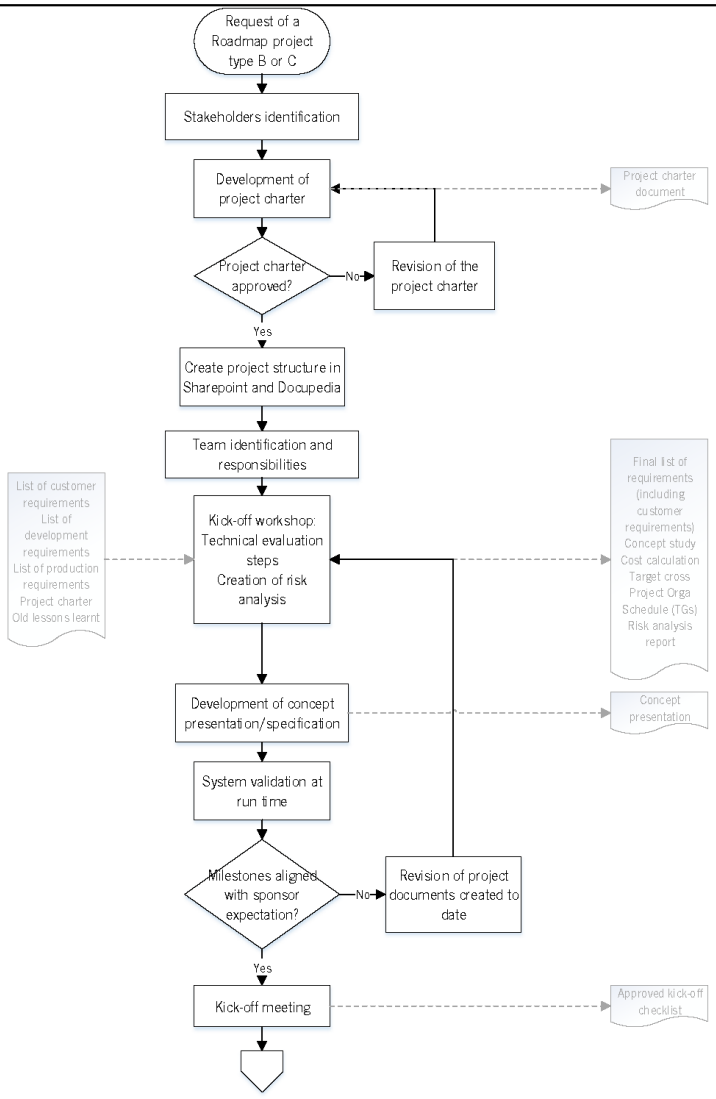
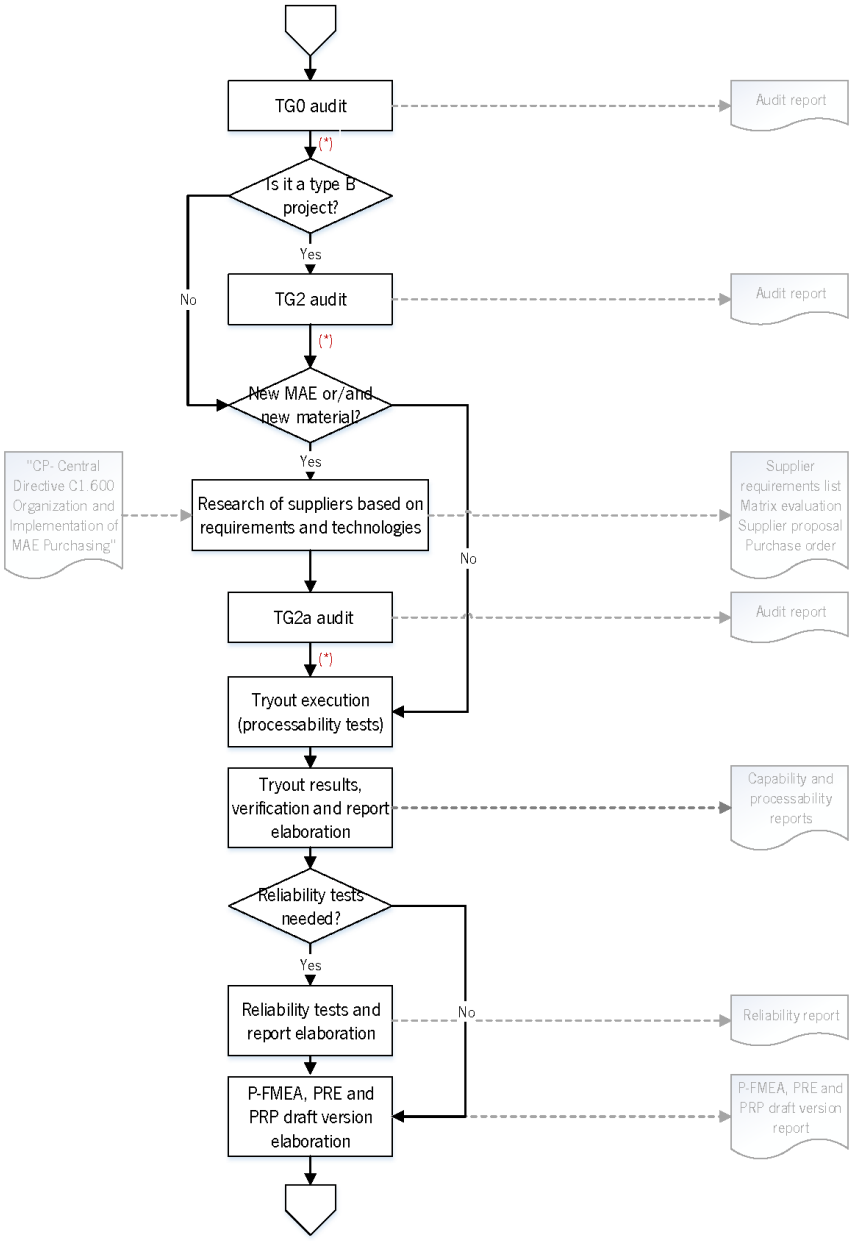
Braga
30 July 2017

Report
Issue Project management
Topic **Process summary**

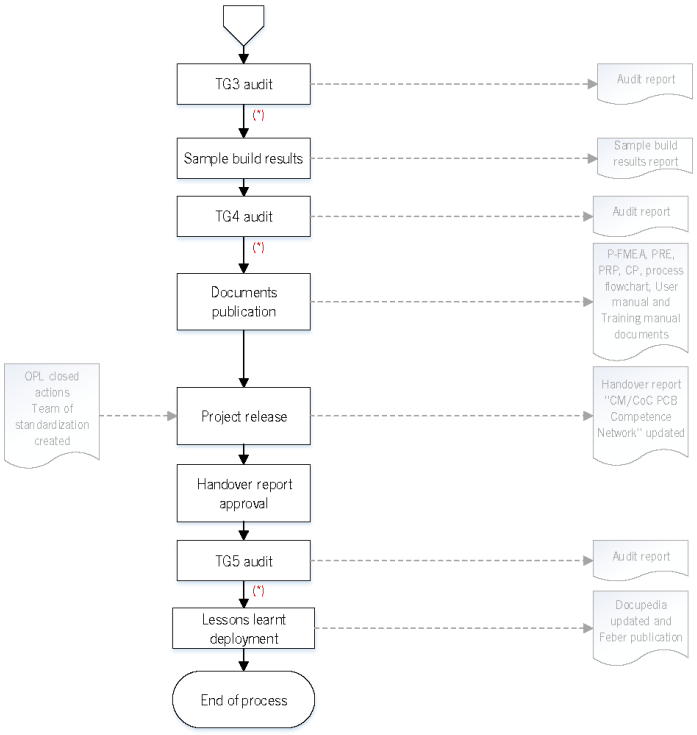
Process flowchart



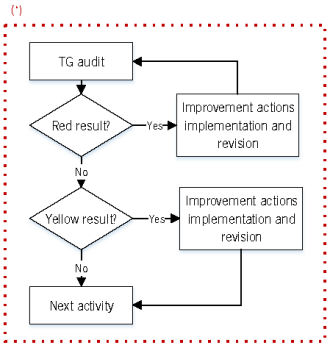
Report
Issue Project management
Topic **Process summary**



Report
Issue Project management
Topic **Process summary**



Legend



Process RASIC matrix

	CM/MFT3 Project Manager	CM/MFT3 Project responsible	CM/MFT3 Head of section	CM/MFT3 section	CM/MFT department	Project sponsor	Key project stakeholders	CM/MFI-Q department	Organization CP	Plants
Stakeholders identification	R	R	R							
Project charter document	R	S, A	A		A	A	A			
Create project structure in Sharepoint and Docupedia	R	I	I	I						
Team identification and responsibilities	R		R							
Kick-off workshop and its reports related	R	R	S	S						
Development of concept presentation/specification and its report	I	R	I	S						
System validation at run time	I	R	I							
Revision of project documents created to date	R	R	S	S						
Kick-off meeting	R	S	S	S		S	S			
Kick-off checklist	R	A	A			A	I			
TG Audit								R		
Audit report	A	A	A		A	A		R		
Research of suppliers based on requirements and technologies and its documents related	I	R	S	S					R	
Tryout execution (processability tests)	I	R	I	S						

BOSCH

From	Our Reference	Tel	Braga
CM/MFT3	Mariana Monteiro	+351(253)30-6100	30 July 2017

Report Issue: Project management
Topic: **Process summary**

Tryout results and verification and report elaboration	I	R	I	S						
Reliability tests and report elaboration	I	R	I	S						
Sample build results and its report	I	R	I	S						
P-FMEA document	See the P-FMEA process RASIC matrix.									
PRE and PRP documents	See "Approval and Information of Process Rules" document[1]									
CP document	See the P-FMEA process RASIC matrix.									
Handover report	R	S	I, A	S	A	A				A
"CM/CoC PCB Competence Network" update	I, S		R	I						R
Lessons learnt deployment	R	R		S, I						

Legend:

R	*Responsible* for completing the work;
A	Authority to *approve* the work once it is complete;
S	*Support* in completing the work and help the person responsible;
I	*Informed* before, during, or at the conclusion of an activity and/or decision without playing an active role in executing the work;
C	*Consulted* to provide expert to technical information, advice or guidance without actively work on the task.

This document becomes effective from: _____

Executed by: _____

Reviewed by: _____

Approved by: _____

[1] https://inside-ilm.bosch.com/irj/go/km/docs/room_extensions_rb/cm_stores/documents/workspaces/a07d92c9-6f75-2d10-8ca4-e6e556eb5410/Process%20Rules/Approval%20and%20information%20of%20process%20rules/PRE_PRP_Approval.xlsx

ANNEX II – PERFORMANCE MEASURES OVERVIEW: PMO AREA

Performance Measurement 2017

Initial date:	01/01/2017	364	(total days)
Final date:	31/12/2017	188	(occcurred days)
Actual date:	08/07/2017	176	(remaining days)

PMO area

n	Name	Type	Formula	Annual Target	Unit	Frequency of measure	Frequency of review	Responsible for measurement	Responsible for data	Objective	Observations	Real value 2016	Real value Jan 2017	Real value Feb 2017	Real value Mar 2017	Actual status	Real value Apr 2017	Real value May 2017	Real value Jun 2017	Actual status
1	Roadmap Projects	Lag	*Cumulative quantity of roadmap projects*	10	-	Monthly	Monthly	PMO area	Head of section	Quantify the projects number ongoing in the section.	Include AIT, IND and Innovation projects.	29	7	7	11		11	11	13	
2	Roadmap Versus Total of Projects	Lead	$\frac{Quantity\ of\ roadmap\ projects}{Quantity\ of\ projects} \times 100$	100%	%	Monthly	Monthly	PMO area	Head of section	Quantify if the number of planned projects (roadmap projects) are higher than unplanned projects.	Unplanned projects are the ones that have a defined project charter with the corresponding costs and schedule. However, weren't planned and don't belong to Roadmap.		88%	88%	92%	89%	92%	92%	87%	89%
3	Projects Cost Plan Fulfilment	Lag	$\frac{Total\ spent}{Total\ available} \times 100$	100%	%	Monthly	Monthly	PMO area	Head of section	Calculate the total projects with own budget spending's.	-	90%	3%	7%	9%	9%	12%	12%	22%	22%
4	TG Audits Done (per projects)	Lead	$\frac{Quantity\ of\ TGs\ done}{Quantity\ of\ TGs\ planned\ to\ do} \times 100$	100%	%	Monthly	Monthly	PMO area	Head of section	Compares the number of TGs done with the number of TGs planned to do.	Mandatory TGs depend on the project type (B, C or non-project).		48%	48%	48%	48%	54%	54%	54%	51%
5	TG4's Alignment with Product C-Sample (per projects)	Lead	$\frac{Quantity\ of\ TG4\ done\ before\ product\ C-Sample}{Quantity\ of\ TG4\ done} \times 100$	100%	%	Quarterly	Quarterly	PMO area	Head of section	Quantify how many TG4 audits were timely performed.	A project milestone is performed TG4 before the C-Sample of product.		100%	100%	50%	83%	50%	50%	50%	67%
6	Green TG Audits (per projects)	Lead	$\frac{Quantity\ of\ TGs\ done\ that\ were\ evaluated\ with\ green\ mark}{Quantity\ of\ TGs\ done} \times 100$	100%	%	Quarterly	Quarterly	PMO area	Head of section	Measure the quality of the roadmap projects ongoing in the section.	Based on the number of "TG Audits Done" performance measure.		100%	100%	100%	100%	100%	100%	100%	100%
7	Projects on Time (per projects)	Lead	$\frac{Quantity\ of\ roadmap\ projects\ on\ time}{Quantity\ of\ roadmap\ projects} \times 100$	100%	%	Quarterly	Quarterly	PMO area	Head of section	Measure if the projects activities are on time according to the schedule defined in the project charter.	-		43%	43%	64%	50%	64%	64%	69%	58%
8	P-FMEAs Planned to Publish	Lag	*Cumulative quantity of new PFMEAs planned to publish*	1	-	Quarterly	Quarterly	PMO area	Head of section	Quantify the P-FMEAs planned to publish during 2017.	-				0				1	
9	P-FMEAs Published on Time	Lead	$\frac{Quantity\ of\ new\ PFMEAs\ published\ before\ C-Sample}{Quantity\ of\ PFMEAs\ published} \times 100$	100%	%	Quarterly	Quarterly	PMO area	Head of section	Quantify if always that a new process occur, a new P-FMEA was created and published before product C-Sample.	Only valid if the performance measure "P-FMEAs Planned to Publish" is > 0.				-				100%	

Legend:	Lead	Improvement performance measure.
	Lag	Result performance measure.
		On course to meet the target.
		It is possible to meet the target.
		The target is unlikely to be met.

ANNEX III – PERFORMANCE MEASURES OVERVIEW: CPR AREA

Performance Measurement 2017

Initial date:	01/01/2017	364	(total days)
Final date:	31/12/2017	188	(occcurred days)
Actual date:	08/07/2017	176	(remaining days)

CPR area

n	Name	Type	Formula	Annual Target	Unit	Frequency of measure	Frequency of review	Responsible for measurement	Responsible for data	Objective	Observations	Real value 2016	Real value Jan 2017	Real value Feb 2017	Real value Mar 2017	Actual status	Real value Apr 2017	Real value May 2017	Real value Jun 2017	Actual status
10	Step Stencils Done (annual)	Lag	*Cumulative quantity of step stencil designs done*	320	-	Monthly	Monthly	CPR area	Head of section	Quantify the number of step stencil designs done.	-	303	13	37	60	19%	80	102	136	43%
11	Step Stencils Done on Time	Lead	$\frac{Quantity\ of\ step\ stencils\ released\ on\ time}{Quantity\ of\ step\ stencils\ done} \times 100$	100%	%	Monthly	Monthly	CPR area	Head of section	Quantify the step stencils that were released on time (before 72 working hours).	Only valid if the performance measure "Step Stencils Done" is > 0.		100%	41%	87%	76%	70%	86%	82%	78%
12	Soldering Thermal Simulations Done (annual)	Lag	*Cumulative quantity of simulations done*	100	-	Monthly	Monthly	CPR area	Head of section	Quantify the number of soldering thermal simulations done.	-	74	2	8	9	9%	9	17	18	18%
13	Soldering Thermal Simulations Done on Time	Lead	$\frac{Quantity\ of\ simulations\ released\ on\ time}{Quantity\ of\ simulations\ done} \times 100$	100%	%	Monthly	Monthly	CPR area	Head of section	Quantify the simulations that were released on time (before 72 working hours).	Only valid if the performance measure "Soldering Thermal Simulations Done" is > 0.		100%	100%	0%	67%	-	63%	100%	74%
14	Footprint Designs Done (annual)	Lag	*Cumulative quantity of footprint designs done*	185	-	Monthly	Monthly	CPR area	Head of section	Quantify the number of footprint designs done.	Updates included.	169	19	25	42	23%	69	87	103	56%
15	CPRs Done (annual)	Lag	*Cumulative quantity of CPRs released*	520	-	Monthly	Monthly	CPR area	Head of section	Quantify the number of component processability released.	CPR report is an approval component report which includes PRNs, PCNs, PRPs, PLEs.	516	53	129	212	41%	256	322	381	73%

Legend:	Lead	Improvement performance measure.
	Lag	Result performance measure.
		On course to meet the target.
		It is possible to meet the target.
		The target is unlikely to be met.

ANNEX IV – PERFORMANCE MEASURES OVERVIEW: LABORATORY ANALYSIS PROCESS

Performance Measurement 2017

Initial date:	01/01/2017	364	(total days)
Final date:	31/12/2017	188	(occcurred days)
Actual date:	08/07/2017	176	(remaining days)

Laboratory

n	Name	Type	Formula	Annual Target	Unit	Frequency of measure	Frequency of review	Responsible for measurement	Responsible for data	Objective	Observations	Real value 2016	Real value Jan 2017	Real value Feb 2017	Real value Mar 2017	Actual status	Real value Apr 2017	Real value May 2017	Real value Jun 2017	Actual status
16	Reports Released (annual)	Lag	*Cumulative quantity of reports released*	356	-	Monthly	Monthly	AIT area	Head of section	Quantify the number of reports released by the CM/MFT3 laboratory.	-	231	31	83	138	39%	165	189	205	58%
17	External Versus Internal Reports Released	Lag	$\frac{Quantity\ of\ internal\ reports\ released}{Quantity\ of\ reports\ released} \times 100$	75%	%	Monthly	Monthly	AIT area	Head of section	Quantify the ratio between the number of internal reports and the total reports issued.	Total of reports cover internal (CM/MFT3 section) and external reports (inside CM).	44%	35%	46%	52%	44%	70%	67%	69%	57%
18	Laboratory Analysis Done (annual)	Lag	*Cumulative quantity of analysis done*	24500	-	Monthly	Monthly	AIT area	Head of section	Quantify the number of analysis done (since one report required more than one analysis).	Include the following analysis: photos; stereomicroscopy; sectional cuts; opticalmicroscopy; SEM; EDS; wettability; STA; environmental evaluation; and X-ray.	15876	913	1984	2751	11%	4174	5885	7515	31%

Legend:		
	Lead	Improvement performance measure.
	Lag	Result performance measure.
		On course to meet the target.
		It is possible to meet the target.
		The target is unlikely to be met.