Universidade do Minho
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junho de 2022

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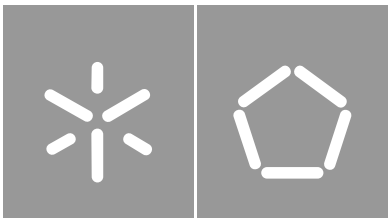

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Risk Management in Manufacturing Systems: Case Study

Dissertação de Mestrado
Engenharia Electrónica Industrial e Computadores

Trabalho efetuado sob a orientação do(a)
Doutor Luís Filipe Castro Louro

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Resumo

Uma vez que vivemos num mundo competitivo é necessário progredir lado a lado com a evolução crescente do mercado, assim sendo, as organizações precisam de ser cada vez mais flexíveis e ter uma forte capacidade de adaptação face às mudanças. Assim sendo, observa-se por parte das empresas o interesse em realizar-se uma análise aos fatores internos e externos que poderão comprometer a continuidade do negócio. Às exigências internas juntam-se as dos seus parceiros e clientes, de forma a garantir o cumprimento dos requisitos, pedem às empresas para obterem as certificações dos padrões de Qualidade. Surge assim a necessidade por parte das empresas de se guiarem por essas normas.

Considerando o avanço tecnológico e as exigências dos seus parceiros, organizações como a *International Organisation for Standardisation*, ISO, e a *International Automotive Task Force*, IATF, têm revisto as suas normas ao longo dos anos, garantindo que se enquadram ao mundo competitivo que vivemos. Neste projeto de dissertação foi dada especial atenção as normas ISO 9001:2015, ISO 31000:2018 e IATF 16949:2016, uma vez que este projeto deverá responder a requerimentos presentes nelas.

Neste projeto, procedeu-se à aplicação do modelo de gestão de riscos proposto na norma ISO 31000:2018, contextualizando-o ao contexto industrial da Continental Mabor Indústria de Pneus, CMIP. Durante a aplicação do modelo, foi realizado o *Risk Assessment* a seis sistemas presente no *Manufacturing Execution System*, MES, onde foram identificados e avaliados os riscos inerentes a eles. Após esta avaliação foi realizada a definição de ações de tratamento, tendo sido definido a necessidade de atualizar ou criar novos planos de contingência, respondendo assim a um requerimento da IATF 16949:2016. Em paralelo com o Risk Assessment foi também executada a atualização do pontos relacionado com a *Direção de Tecnologia e Informação*, DTI, no plano de contingência da CMIP.

As técnicas utilizadas para a exposição dos resultados foram a análise de modos de falhas e efeitos (FMEA) e o Registo de riscos (RR). Como conclusão deste projeto foram apontadas as vantagens e desvantagens das técnicas aplicadas, assim como foram identificadas as suas limitações. A implementação de um processo de gestão de riscos, permitiu à organização agir de forma preventiva no processo de produção.

Palavras-chave: Gestão de risco; Sistema de Gestão da Qualidade; ISO3 31000; ISO 9001; IATF 16949; Risco

Abstract

Since we live in a competitive world, it is necessary to progress side by side with the growing evolution of the market. Therefore, organisations need to be increasingly flexible and have a solid ability to adapt to changes. Therefore, companies are interested in analysing the internal and external factors that could compromise the continuity of the business.

Furthermore, their customers and partners want assurance of the fulfilment their requirements, which results in the companies obtaining the certifications of the Quality standards to provide evidence to their partners and customers.

Considering technological advances and the demands of their partners, organisations such as International Organisation for Standardisation (ISO) and International Automotive Task Force (IATF) have revised their standards over the years, ensuring that they fit the competitive world in which we live. In this dissertation project, special attention was given to the ISO 9001:2015, ISO 31000:2018, and IATF 16949:2016 standards since this project must respond to the requirements.

In this project, the risk management model proposed in the ISO 31000:2018 standard was applied, contextualising it to the industrial context of CMIP. During the application of the model, six systems present in the MES were the target of the Risk Assessment, where the identification and evaluation of their inherent risks occur. After this evaluation, the next stage was the Risk Treatment, where the definition of the need to update or create new contingency plans occurred, thus responding to a requirement of IATF 16949:2016. In parallel with the Risk Assessment, updating the points related to the DTI in the CMIP contingency plan was also carried out.

The techniques used to present the results were the failure mode and effect analysis (FMEA) and the Risk Register (RR). The conclusion of this project debated the advantages and disadvantages of the techniques applied and their limitations. Implementing a risk management process, allowed the organisation to act preventively in the production process.

Key words: Risk Management; QMS; ISO3 31000; ISO 9001; IATF 16949; Risk

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Acronyms

APA - Armazém do Produto Acabado
AVSQ - Associazione nazionale dei Valutatori di Sistemi Qualità
BDA - Business Dependency Analysis
BIA - Business Impact Analysis
CCM - Central Manufacturing
CGMS - Conti Global Manufacturing System
CGRS - Conti Global Recipe System
CGUI - Client User Interface
CKU - Central Key User
CMIP - Continental Mabor Indústria Portugal
CSMI - Continental Standard Machine Interface
CST - Commercial Speciality Tires
DEI - Direção de Engenharia Industrial
DEM - Direção de Engenharia e Manutenção
DEP - Direção de Engenharia de Processo
DIL - Data Integration Layer
DIP - Direção de Industrialização do Produto
DOL - Direção de Operações e Logística
DP - Direção de Produção
DQ - Direção da Qualidade
DSIA - Direção de Segurança Industrial e Ambiente
DTI - Direção de Tecnologias de Informação
EWM - Extended Warehouse Management
FEFO - First Expired First Out
FFDACS - Final Finishing Data Acquisition and Control System
FMEA - Failure Mode and Effects Analysis
FPM - Failure Process Matrix
GUTS - Globally Unified Tire Specs
HBS - High Base Storage
IATF - International Automotive Task Force
IPC - Industrial PC

ISO - International Organisation for Standardisation
KM - Karcass Machine
LKU - Local Key User
MCAT - Material Control and Traceability
MES - Manufacturing Execution System
MMS - Mixing Manufacturing System
MSS - Manufacturing Suite Systems
MTE - Manufacturing Technology Engineering
MTL - Message Transformation Layer
OE - Original Equipment
OEM - Original Equipment Manufacturer
PDCA - Plan-Do-Check-Act
PLT - Passenger and Light truck Tires
PoMS - Process oriented Management System
PU - Pressure Unity
QM - Quality Management
QMS - Quality Management System
RKU - Regional Key User
RPN - Risk Priority Number
RR - Risk Register
SFI - Shop Floor Integration
VDA - Verband der Automobilindustrie

Chapter 1

Introduction

1.1 Motivation

Currently, the organisational environment requires organisations to focus on a global perspective with defined and innovative objectives (Geissdoerfer, Vladimirova, & Evans, 2018). In order to gain a competitive advantage, it is critical to embrace different challenges with innovative approaches, focusing on long-term benefits in today's global economy (Imasiku, 2021).

The concept of risk can be defined and explained in different ways. This difference depends on its context and the perspective of the discussion. For example, for Kaplan and Garrick, a risk is an uncertainty combined with loss or damage ((Kaplan & Garrick, 1981); (Sommerville, 2011)). While for Kahn and Zsidisin, risk can be an event where both the possibility of losses and the opportunity for gains will occur (Khan & Zsidisin, 2012). Therefore, these two hypotheses must be recognised to recognise the existence of a risk (Abuhav, 2017).

According to International Organisation for Standardisation, ISO 31000, risk management coordinates the activities that direct and control an organisation regarding risks (ISO, 2018b). Therefore, risk management processes aim to mitigate the negative impact of internal and external disturbances to eliminate production interruptions, quality problems and financial losses (ISO, 2015b).

At Continental, the control of some of its production processes and associated disruptions already have defined contingency plans. However, these need to be revisited and reassessed since there is a possibility that they are outdated. On the other hand, new systems require a detailed risk assessment and the creation of their contingency plans. As a result of this situation, this dissertation will have the primary objective of identifying the most critical risks that may be present in the company's production systems and to find proactive and reactive actions for the mitigation, elimination or acceptance of these risks.

1.2 Objectives

This dissertation proposal's main objective is to identify and analyse risks in production systems present in a factory environment through a case study and characterising contingency measures for each risk.

To accomplish this goal, it will be necessary:

- Characterise the production systems;
- Identify the risks present in each system;
- Characterise the risks and create the risk matrix;
- Identify current contingency plans, verify their feasibility and update them when necessary;
- Create contingency plans for the remaining risks;
- Carry out risk treatment plans;
- Normalise work procedures.

With this goal, the intended results are:

- Increase the efficiency and productivity of information systems, in case of failure;
- Ensure business continuity;
- Reduce waste (movements, unnecessary operations, among others.);
- Decrease the time of unplanned stops;
- Reduce the number of non-conforming products;
- Reduce costs.

1.3 Dissertation Structure

This dissertation is organised in a set of seven chapters. The first chapter is the introduction, where the work is contextualised and the objectives to be achieved in carrying it out are presented. In this chapter, the structure of the dissertation is also presented.

In the second and third chapters, the bibliographic review is presented. The second chapter begins with a short presentation of the Quality Management System, QMS, serving as a context for the ISO 9001:2015 and International Automotive Task Force, IATF 16949:2016 standards. The presentation of the ISO 9001:2015 standard includes an explanation of the rules associated

with it, its values and standards that constitute the principles of quality management, the process approach and the Plan-Do-Check-Act (PDCA), cycle. In chapter three, the contextualisation of risk management is carried out, starting by presenting the definition of risk for several authors. The risk management process is then explained, contextualising the ISO 31000:2018 standard. Risk management techniques are also introduced, including Brainstorming, Failure Model and Effects Analysis (FMEA), Scenario Analysis, Risk Register, Structured or semi-structured interviews, Business Impact Analysis (BIA) and Consequence and likelihood matrix. Finally, these risk management tools are presented due to their application in this case study.

The fourth chapter is dedicated to the company's characterisation, where the history and organisational structure are mentioned, explaining the production process, Manufacturing Execution System (MES), and the quality management system.

The fifth chapter explains the methodology used for this case study through the various stages carried out during the project and a brief explanation of the approach used between 2012 and 2014.

The following chapter is devoted to the results. In the first phase, the results obtained in the Risk Assessment of the Manufacturing Execution System, MES, are explained, and then the results of the Risk Assessment for the Continental Mabor Indústria Portugal (CMIP) contingency plan. Finally, the results of creating contingency plans for the proposed systems are exposed.

The last chapter is dedicated to the conclusions of the work, where the limitations found throughout the project are also exposed, as well as some indications for future work.

Chapter 2

Quality Management System

The ISO defined the concept of Quality Management Systems (QMS) due to the need to delineate how an organisation is aware of the requirements of its customers and interested parties that interact with its work. This concept does not specify which objectives are related to quality or how to respond to clients' needs. However, QMS requires that organisations define those objectives and continuously improve their processes to ensure them.

The ISO 9001 affirms that "the adoption of a quality management system is a strategic decision for an organisation that can help to improve its overall performance and provide a sound basis for sustainable development initiatives." (ISO, 2015a) Considering this statement, implementing a Quality Management System is a tool to help the organisation achieve improvements.

This chapter exposes the principles of quality management, the process approach, risk-based thinking and the impacts and perceptions of both ISO 9001:2015 and IATF 16949 certifications.

2.1 ISO 9001

ISO 9001, an international standard, specifies a QMS's requirements. This standard is part of the ISO 9000 family of standards and is the most widely used of the group because it is the only one that allows enterprises to achieve certification. The ISO 9000 standard family includes three norms. In addition, numerous supporting standards, technical reports, and guidance materials sustain these norms:

- **ISO 9000:2015** - Quality management systems - Fundamentals and vocabulary (ISO, 2015b);
- **ISO 9001:2015** - Quality management systems - Requirements (ISO, 2015a);
- **ISO 9004:2018** - Quality management - Quality of an organisation - Guidance to achieve sustained success (ISO, 2018a).

Organisations elect ISO 9001 to ensure that these requirements are met, both in items delivered and purchased, due to the need to demonstrate the ability to consistently supply services

and products that meet regulatory and customer requirements. As a result, ISO 9001 is the most widely known management system standard worldwide, with over one million firms using it.

ISO 9001 was issued for the first time in 1987 by the International Organisation for Standardisation, an international non-governmental organisation comprised of members of national institutions from over 160 nations. In September 2015, ISO released the current version of ISO 9001. The two goals of this revision are to keep the company's relevance in the industry and continue to provide companies with superior performance (Braun, 2005). Any organisation can use ISO 9001:2015, regardless of size or industry, because its goals include assisting the organisation and continuously improving its processes (Anttila & Jussila, 2017).

Each chapter of ISO 9001:2015 concentrates on a different set of requirements. Working together to support the quality management system and being the following:

- **Chapters 0 to 3** - Introduction and scope of the standard
- **Chapter 4** - Context of the organisation
- **Chapter 5** - Leadership
- **Chapter 6** - Planning
- **Chapter 7** - Support
- **Chapter 8** - Operation
- **Chapter 9** - Performance evaluation
- **Chapter 10** - Improvement

2.1.1 Principles of Quality Management

The ISO 9001 has as a pillar the seven quality management principles. This norm helps organisations continually add value to their customers. Implementing a quality management system becomes straightforward when these seven pillars are defined. The following topics discuss the seven principles of quality management.

Principle 1 - Customer focus

According to the 9001:2015 standard, companies need their customers. Therefore, companies must understand their current and future needs, strive to meet their criteria and even exceed their expectations.

> "The primary focus of quality management is to meet customer requirements and to strive to exceed customer expectations." (ISO, 2015b)

Principle 2 - Leadership

Managers' responsibility is to lead the company, set goals and create the conditions for success. It is crucial to create an internal atmosphere that encourages employees to participate in achieving the goals.

> "Leaders at all levels establish unity of purpose and direction and create conditions in which people are engaged in achieving the organization's quality objectives." (ISO, 2015b)

Principle 3 - Engagement of people

The essence of an organisation is its people. The key to successfully and efficiently managing a company is to involve all people, from top to bottom of the management chain.

> "Competent, empowered and engaged people at all levels throughout the organization are essential to enhance the organization's capability to create and deliver value" (ISO, 2015b)

Principle 4 - Process Approach

The QMS is composed of processes that are interconnected. This concept is discussed in more detail later in section 2.2.

> "Consistent and predictable results are achieved more effectively and efficiently when activities are understood and managed as interrelated processes that function as a coherent system" (ISO, 2015b)

Principle 5 - Improvement

Organisations must continue to focus on improvement to achieve the set goals and ensure customer satisfaction.

> "Successful organizations have an ongoing focus on improvement" (ISO, 2015b)

Principle 6 - Evidence-based decision making

As in day-to-day life, decisions made in organisations have consequences.

> "Decisions based on the analysis and evaluation of data and information are more likely to produce desired results" (ISO, 2015b)

Principle 7 - Relationship Management

Organisations must be aware of the relationships they form.

> "For sustained success, organizations manage their relationship with relevant interested parties, such as providers" (ISO, 2015b)

2.1.2 Advantages and disadvantages of the implementation of a QMS

Incorporating a quality management system in a company can occur for various reasons or considerations.

The implementation of a quality management system can be beneficial to the organisation. These benefits may include opening up new markets and maintaining existing markets or one of those, increasing competitiveness, increasing confidence in working methods, increasing employee involvement and motivation, reducing costs, improving corporate image, continuous improvement, international recognition and inclusion in a list of leading companies in the world market.

Despite the benefits of adopting a QMS, several challenges stand in the way of adoption. These include the lack of senior management involvement, the cost of implementation and maintenance, the time required to develop the system, the difficulty sustaining staff enthusiasm and the unwillingness to change.

2.2 Process Approach

As referred to in the previous section, several interconnected processes integrate all organisations, allowing them to achieve consistent results. A process is a collection of activities that employ resources to convert inputs into outputs, with one output becoming the input of the following (Kowalik & Klimecka-Tatar, 2018).

The process approach is one of the seven quality management principles. According to the standard, activities are understood and managed more effectively and efficiently when they are understood and managed as inter-relational processes that function as a coherent system. A process approach is a powerful way to coordinate activities to create value for the customer and other stakeholders. Therefore, it must be employed consistently in QMS planning, implementation, maintenance, and improvement (Zhang & Russell, 2005).

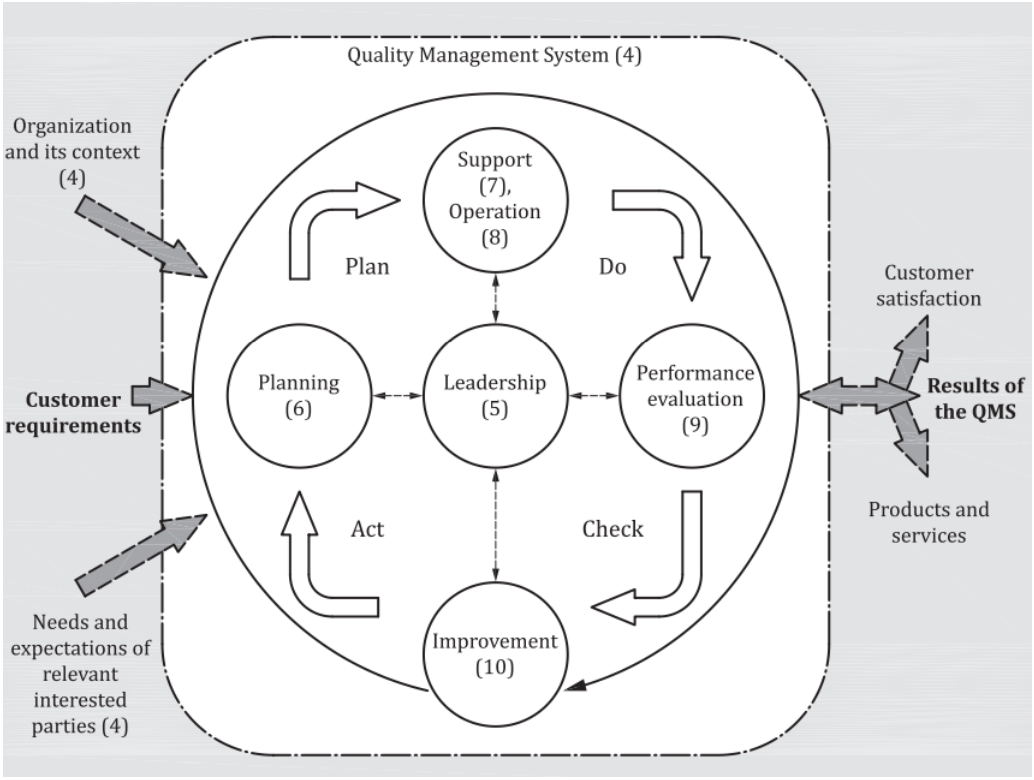

Figure 2.1: Representation of the structure of ISO 9001:2015 in the PDCA cycle - the numbers in the brackets refer to the clauses in the ISO 9001:2015. (adapted from (ISO, 2015a))

Each process has stakeholders, internal or external, which the process's performance can influence. These stakeholders determine the process's conclusion based on their needs and expectations. The ISO 9001 standard recommends using the PDCA cycle to respond to the many stakeholders and ensure the befitting operation of the process approach (see figure 2.1). Using this cycle, the manager must:

- Determine the expected results;
- Define the path to achieve the necessary resources;
- Implement the defined actions;
- Monitor the performance of the activities concerning the achievement of the expected results.

The PDCA cycle aims to maintain and improve process performance in all stages of the QMS (Isniah, Purba, Debora, et al., 2020).

The ISO Guide to Support the Use of the Process Method and the ISO 9001:2015 standard highlight the favourable outcomes of using this approach. Both identify the following benefits:

- Transparency in organisational operations;

- Providing consumers and other stakeholders with confidence in the organisation's consistent performance;
- Encouraging people to participate and clarify their duties;
- Understanding and consistent fulfilment of requirements;
- Evaluation of the processes in terms of added value.
- Achieving effective process performance with consistent, enhanced, and predictable results;
- Process enhancement based on data and information analysis.

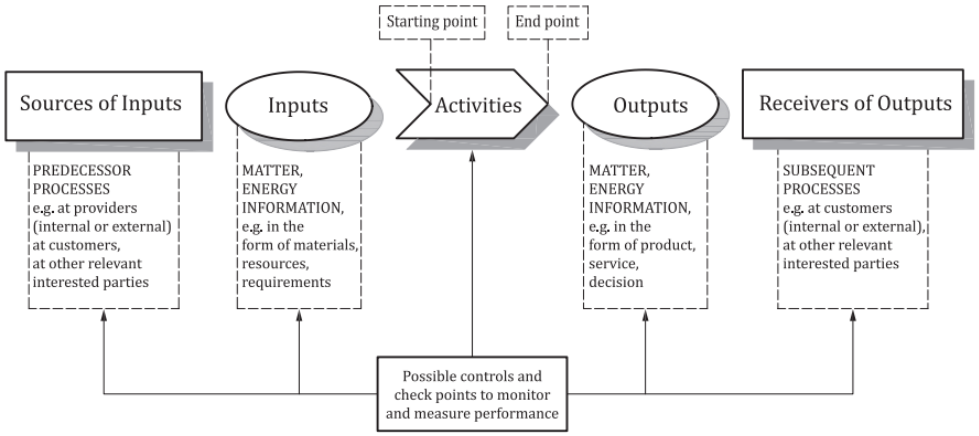

Figure 2.2: Schematic representation of the elements of a single process
(adapted from (ISO, 2015a))

The ISO 9001:2015 standard recommends a schematic depiction of any process and portrays the interplay between its aspects, as illustrated in the figure 2.2 to focus more on the process approach.

2.2.1 PDCA cycle

As previously stated, ISO 9001 recommends the adoption of the PDCA cycle. Deming's quality management tool strives to make processes more nimble, clear, and objective for organisations and businesses (Best & Neuhauser, 2005).

Most firms now prefer the continual improvement of their processes and use this cycle to improve their performance (Realyvásquez-Vargas, Arredondo-Soto, Carrillo-Gutiérrez, & Ravelo,

2018). This approach is a four-step management method that tries to control and improve processes and products. There is the possibility of applying this cycle to the entire quality management system or per process. The four steps of the method can be specified and schematised in figure 2.1, as explained in the following topics.

Plan

It is the stage at which the objectives, means of achieving them, and responsibilities are specified. At the end of this phase, it is necessary to establish:

- Who is responsible for the process and those responsible for its execution;
- What are the outputs produced by the process;
- What are the events that promote the activity of the process;
- Where does the process take place;
- What are the risks and opportunities of the process.

Do

During the verification step of the process, it is determined whether the execution went as intended and whether the final outputs were as expected. This step has two parts: monitoring and analysing.

Check

Monitoring entails gathering process results and comparing them to the anticipated results of the planning stage. The analysis encompasses thoroughly examining the process to determine what, if any, deviations occurred. Planning reform may result from the latter to correct any anomalies that may have existed.

Act

This stage ensures constant improvement of the process. Then, actions are defined for greater efficiency and implemented based on the results obtained.

2.3 IATF 16949

The International Automotive Task Force (IATF) produced the first edition of the ISO/TS 16949 standard in 1999 to standardise the various evaluation and certification processes used in the automotive supply chain (IATF, 2016).

The ISO/TS 16949 standard created a uniform set of techniques and methods for product and process development. This standard aims to integrate country-specific evaluation and certification systems such as the QS 9000 in North America, the Associazione nazionale dei Valutatori di Sistemi Qualità (AVSQ) in Italy, the EAQV in France, and the Verband der Automobilindustrie (VDA) in Germany. To address the issue, IATF members collaborated with car manufacturers' associations to create a uniform standard that incorporated the individual requirements of each manufacturer and was accepted by all.

In the literature, authors regard ISO/TS 16949 as an extremely difficult standard normative since it controls a very austere sector with comprehensive specialised standards.

The most recent version of the standard, IATF 16949:2016, was published in October 2016, replacing the 2009 version. It varies from the previous one in that it is built on a high-level structure to ensure consistency, aligns multiple management system standards, provides sub-clauses that are compatible with the top-level organisation, and employs a common language across all standard benchmarks.

The IATF 16949:2016 technical specification is in line with the ISO 9001:2015 standard. The normative reference establishes detailed requirements on the quality management system for the production process and assembly and maintenance of products related to the automotive industry. This revision also incorporates IATF requirements for Original Equipment Manufacturer (OEM) and customer-specific requirements (CSR), among other specifications.

The standard's chapters are identical to ISO 9001:2015, although they incorporate some definitions specific to the automotive sector. The goal of this standard, according to promoters, is to create a global management system that provides continuous improvement, with an emphasis on preventing failures, reducing variation and losses in the supply chain, managing and monitoring non-conforming products, and focusing on risks and opportunities.

The IATF publishes a list of sanctioned Interpretations regularly, changing the interpretation of a regulation or a requirement, which then serves as the foundation for a nonconformity (IATF, 2021).

When planning for the QMS, the organisation must evaluate, both external and internal, relevant challenges to its purpose and strategic direction and those impacting the organisation's capacity to accomplish the desired results of its quality management system. It must also take into account statutory and regulatory restrictions. The organisation identifies the risks and opportunities to:

- Assure that the QMS will accomplish its intended goals;
- Enhance favourable impacts;
- Prevent or mitigate unwanted consequences;
- Achieve improvement.

The organisation must design steps to address these risks and opportunities, as well as how to:

1. Integrate and implement these activities into its QMS processes;
2. Evaluate their efficacy.

Actions taken to manage risks and opportunities must be appropriate to the possible impact on product and service conformance.

2.3.1 Contingency plans

A contingency plan is a plan of action to respond to future events that may or may not affect an organisation. In most cases, the organisation develops a contingency plan in response to an incident that could jeopardise a company's reputation or ability to do business.

The contingency plan is a proactive strategy, in contrast with a risk response plan, which is more reactive to a risk event. A contingency plan aims to address disruptive events so that organisations are ready if and when they occur.

While the organisation can determine each key point to integrate the contingency plans, it must consider the guidelines provided by IATF. Therefore, the organisation must:

- Identify and assess internal and external risks to all manufacturing processes and infrastructure equipment required to maintain output and meet customer needs;
- Define contingency plans based on the level of risk and the impact on the client;
- Prepare contingency plans for supply continuity in the event of, but not limited to, crucial equipment failures; interruptions from externally provided products, processes, and services; recurring natural disasters; fire; pandemics; utility interruptions; cyber-attacks on information technology systems; labour shortages; or infrastructure disruptions;
- Include a notification mechanism to the customer and other interested parties for the extent and duration of any issue affecting customer operations as an addition to the contingency preparations;

- Test the effectiveness of the contingency plans regularly (e.g., using simulations as applicable); for cybersecurity, testing may involve a simulation of a cyber-attack, regularly monitoring for specific threats, identification of dependencies, and prioritising vulnerabilities. The testing is proportionate to the risk of consumer inconvenience;
- Conduct contingency plan evaluations (at least once a year) with a multidisciplinary committee that includes top management and updates as needed;
- Document the contingency plans and keep records of any revisions, including the person(s) who authorised the modification(s);
- Contingency plans should include the implementation of appropriate personnel training and awareness.

Contingency plans shall include provisions confirming that the manufactured product will continue to meet customer specifications when production resumes, for example, following an emergency where production stopped.

Chapter 3

Risk Management

Every company faces various risks that affect its goals or opportunities independently of its sector.

Organisations should commit to approaching risk management proactively and consistently to ensure success (PMBOK, 2021). This process increases the success rate and decreases the failure rate in conjunction with the uncertainty of reaching every global goal (ISO, 2018b).

Risk management is a process in which organisations analyse the inherent risk to their activities. The methodical use of risk management methods helps reduce risks to ensure as efficiently and effectively as feasible to meet the objectives(António, Teixeira, & Álvaro Rosa, 2019). This systematic application comprises procedures for identifying, analysing, assessing, treating, monitoring and reviewing risks that may jeopardise the achievement of these goals. As a result, it is a methodical management approach that tries to respond consistently and proactively against the numerous risks linked with current, past, and future actions.

The standard of principles and guidelines for risk management, ISO 31000:2013, states that this process must become part of the organisational processes and insert into all practices and operations of the organisation in a relevant, effective and efficient way (ISO, 2018b).

While organisations naturally deal with risks as part of their daily operations, the ISO created the ISO 31000 to provide a series of principles to be satisfied to ensure an effective system. The standard recommends the development, implementation and continuous improvement of the process to integrate the culture of risk in the operations and governance of the institutions (ISO, 2018b).

Any change brings risks, but it is also inextricably linked to opportunities. In other words, every action raises the probability of unanticipated occurrences happening, which might have a positive or negative consequence.

According to the ISO 31000:2013 standard, there are various benefits to implementing a Risk Management process, some of which are as follows:

- Increase chances of reaching the company's objectives;
- Recognise the importance of identifying and addressing risk within the organisation;

- Improve the identification of opportunities and threats;
- Comply with all applicable legal, regulatory duties and international standards;
- Enhance both required and voluntary reporting;
- Enhance governance;
- Increase stakeholder trust and the organisation's credibility;
- Create a solid foundation for decision-making and planning;
- Improve controls;
- To effectively address risk, allocate and use resources;
- Increase the efficacy and efficiency of the organisation's operations;
- Improve performance in the areas of safety, health, and environmental protection;
- Enhance companies' loss prevention and incident management;
- Reduce losses;
- Enhance organisational learning.

The following sections discuss the concept of risk, the risk management process and techniques for its execution.

3.1 Risk

The first step in risk management is understanding the meaning of **risk**. This concept is similar to others like the **unforeseen**, the **vulnerability**, the **accident** and the **disturbance** (Ennouri, 2015).

The ISO 31000:2018 defines risk as an "effect of uncertainty on objectives" (ISO, 2018b). The standard considers this effect as a deviation from the expected, which can be negative or positive. The uncertainty of this influence refers to a state of insufficient information related to an event's comprehension or knowledge, its outcome, or possibilities.

Organisations understand risk as to the adverse effect it can have. However, depending on their potential impact, different types and degrees of risk can be treated or assumed (PMBOK, 2021).

Summarily, risk can be the probability of a failure or deviation in the system. In order to prevent this event or mitigate it, the organisation should study the consequences and impact of the associated risks.

3.2 Risk Management Process

Several authors, like Srinivas, divide the risk management process into four phases being those the identification, analysis and evaluation, treatment and monitoring (Srinivas, 2019). While the ISO 31000 establishes six core steps, being those:

- Communication and Consultation;
- Scope, Context, Criteria;
- Risk Assessment;
- Risk Treatment;
- Recording and Reporting;
- Monitoring and Review.

Three of these steps are transversal to the entire process, as indicated in Figure 3.1 and the following topics.

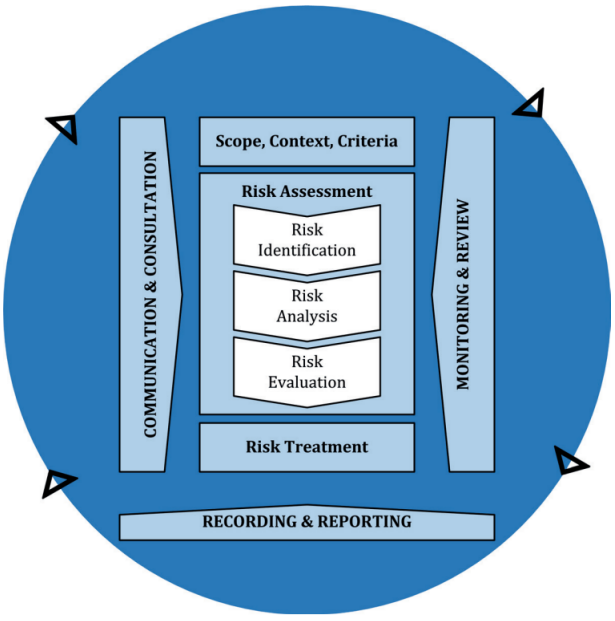

Figure 3.1: Risk Management process. (adapted from (ISO, 2018b))

The current dissertation project adheres to the risk management method outlined in ISO 31000 (figure 3.1).

Communication and Consultation

Communication and consultation should occur before, during, and after an organisation's risk management systems implementation, as shown in figure 3.1.

The specific plans for applying the methodology should be established at the initial stage, as should a clear communication strategy with all stakeholders involved.

The main objectives of ongoing communication and consultation are to:

- Provide a solid foundation for the implementation of the system;
- Ensure collaboration among all staff;
- Ensure a common understanding of risk concepts at the institution.

According to the standard, key expected outcomes of effective development of this activity are to:

- Accelerate understanding of the corporate context;
- Ensure a clear understanding of stakeholder needs and interests;
- Secure appropriate risk identification;
- Confirm and support treatment plans.

Establish context

A better understanding of the context in which the organisation develops its activities provides a framework for faster and more accurate risk identification and analysis.

There are two types of contexts: external and internal. The external context refers to the environment in which the organisation develops its activities.

A good understanding of the external context ensures the objectives and considers the concerns of external stakeholders when developing risk criteria.

The ISO 31000 includes some specific issues to be considered as part of the external context assessment while noting that other issues may be identified, depending on the organisation's area of activity:

- Social, political and cultural environment;
- Legal and regulatory environment;
- Financial and economic environment;
- Market and competitive environment;

- International, national, regional and local environment;
- Key influencing factors and trends related to the organisations' operations;
- Relationships with partners and other external stakeholders.

The internal context is the environment in which the institution develops its risk management system.

The main objective of defining and establishing it is to ensure that the new system and tools for risk management are consistent with the culture and processes of the institution and follow the strategies already defined.

Some of the aspects that businesses should explore are:

- Organisational structures and governance;
- Policies, objectives and approaches;
- Resources and expertise;
- Relationships and perceptions of internal stakeholders;
- Organisational culture;
- Information and communication flows;
- Standards and guidelines adopted by the organisation;
- Characterisation of contractual arrangements.

Risk Identification

According to the ISO, the organisation should identify sources of risk and impact areas. The main goal is to create a comprehensive list of risks that can accelerate or prevent the achievement of objectives.

The organisation should develop a comprehensive tool and internal methodology for identifying risks in day-to-day operations.

The standard recommends that risk should be considered with internal and external sources, regardless of whether they are under the organisation's control or the root cause is not clearly defined.

Risk Analysis

After establishing a risk inventory, the organisation should guarantee a thorough understanding of the risk, including its typology and assignment to a specific area or process.

The risk analysis includes an indication of the source and causes of the risk; at the same time, the assets or subjects affected by the identified situation should be named and listed. Risk analysis responds to qualitatively understanding and classification of identified risks. Depending on the purpose of the examination and the information available, it may vary in detail.

Risk Evaluation

The risk evaluation supports the decision-making process based on the risk analysis results. Therefore, the ISO recommends classifying the analysed risks according to their probability and the extent of their impact.

This assessment serves as a tool for continuing the risk management process. The organisation should establish its criteria for carrying out this activity based on the information gathered when establishing the context.

Risk Treatment

Considering the risk evaluation results, the organisation should identify a treatment method for each priority risk in the inventory. There are several recommended alternatives for treating risks based on the level of risk identified in each situation. As mentioned in the standard ISO 31000, risk treatment involves a cyclical process of assessing, determining treatment options and reassessing the risk after implementing these improvements.

As mentioned in the standard ISO Guide 73, there are four main recommended methods to address identified risks in organisations: Reduce, Transfer, Avoid and Accept. Risk owners and managers make an informed decision by assessing and prioritising the identified risks. In addition, they are responsible for the continuous development of the activities that could be affected by a particular one.

- Reducing the risk means changing either its occurrence or impact or both. Therefore, risk managers are usually encouraged to develop and monitor these control measures.
- Transferring the risk to insurance companies or outsourcing activities is another way of dealing with it; this option usually requires financial resources and may contribute to other risks related to third parties.
- Avoiding the risk means stopping the activity that causes it. This method aims at high-risk activities that do not contribute to achieving the organisation's objectives.

- Accepting the risk means continuing the activity or process and bearing the consequences of that decision. Risk managers choose this strategy based on the impact of a hazard or opportunity on the organisation.

The next step in defining specific controls and plans for the organisation is establishing the best strategy for each risk. This definition always takes into account risk analysis and assessment.

Monitoring and Review

Monitoring and review is the second component of the methodology that should run through the development of the risk management process to ensure a continuous review process. The most important outcome of an effective monitoring and review process is to ensure that opportunities for improvement are identified and implemented during the development of the previous steps.

As part of this process, it may be productive to involve top management or relevant internal stakeholders previously identified through the risk management process.

Recording and Reporting

Recording and reporting is the third component of the risk management process, which is transversal to the whole process. It ensures that the process and its outcomes are documented and reported through appropriate mechanisms.

The objective of recording and reporting is to:

- Communicate risk management activities and outcomes throughout the organisation;
- Provide information for decision-making;
- Improve risk management activities; Support interaction with stakeholders, including those who are responsible and accountable for risk management.

Reporting is an integral part of corporate governance and should enhance the quality of dialogue with stakeholders and assist top management and boards fulfil their responsibilities.

Factors to be considered in reporting include:

- Different stakeholders and their specific information needs and requirements;
- The cost, frequency and timeliness of reporting;
- The method of reporting;
- Relevance of information to business objectives and decision-making.

3.3 Risk Management Techniques

3.3.1 Brainstorming

Brainstorming is a process used to stimulate and encourage a group of people to develop ideas on one or more topics of any kind. However, effective brainstorming requires a conscious effort to ensure that the thoughts of others are used as a tool to stimulate the creativity of each participant. Analysis or critique of ideas is done separately from brainstorming.

This technique produces the best results when an expert facilitator is available. The facilitator can provide the necessary stimulation but does not restrict thinking. The facilitator encourages the group to cover all relevant areas and ensures the recording of ideas from the process for later analysis.

Brainstorming can be structured or unstructured. In structured brainstorming, the facilitator breaks down the topic to be discussed into sections and uses prepared prompts to generate ideas or a new topic when the current is exhausted. Unstructured brainstorming is often a less formal approach. In both cases, the facilitator sets a train of thought in motion, encouraging everyone to generate ideas. The pace is maintained so that the ideas can stimulate lateral thinking. The facilitator may suggest a new direction or use another creative thinking tool if one line of thinking is exhausted or the discussion strays too far. The aim is to gather as many different ideas as possible for later analysis.

Table 3.1: Strengths and Weaknesses of the brainstorming technique

Strengths	Weaknesses
- It encourages imagination and creativity, which helps identify new risks and novel solutions; - It is useful where there is little or no data; - It is a practical where new technology or novel solutions are required; - It is relatively quick and easy to set up. - It involves key stakeholders and hence aids communication and engagement;	- It is challenging to demonstrate that the process has been comprehensive; - Groups tend to generate fewer ideas than individuals working ideas;. - Group dynamics might mean some people with valuable ideas stay quiet while others dominate the discussion; - Encouraging creative thinking and new ideas can mean that conversation does not stay focused on the subject.

Groups have been shown to produce fewer ideas in practice than the same people working individually. Example:

- In a group, ideas converge rather than diversify;

- The delay that occurs when people wait to have their say blocks ideas;
- People tend to make a less mental effort in a group.

These tendencies can be reduced by:

- Allowing people to work alone some of the time.
- Diversifying teams and changing the composition of teams.
- Combining with techniques such as the nominal group technique or electronic brainstorming. These techniques encourage more individual participation and can be set up to be anonymous, which also avoids personal political and cultural issues.

The table 3.1 exposes the principal strengths and weaknesses of this technique for eliciting views.

3.3.2 Structured or semi-structured interviews

Individual interviewees are asked a series of prepared questions in a structured interview. A semi-structured interview is similar but leaves more freedom for a conversation to explore questions that may arise, creating an explicit opportunity to explore areas the interviewee may wish to cover.

Table 3.2: Strengths and Weaknesses of the structured or semi-structured interviews technique

Strengths	Weaknesses
- They give people time to think about a topic. - Person-to-person communication can allow for a more in-depth consideration of issues than a group approach. - Structured interviews allow for the inclusion of more stakeholders than a face-to-face group.	- Interviews are time-consuming to plan, conduct and analyse. - They require a certain level of expertise if the interviewer is to provide unbiased responses. - Interviewee bias is tolerated and not mitigated or eliminated by group discussions. - Interviews do not stimulate the imagination (which is a characteristic of group methods). - Semi-structured interviews provide a considerable amount of information in the interviewee's own words. It can be arduous to put this clearly into a form suitable for analysis.

Questions should be open-ended and phrased in a simple and appropriate language for the

interviewee. In addition, the interviewer should prepare possible follow-up questions for clarification.

The interviewer should test the questions with people who have a similar background to the interviewers to ensure that the questions are not ambiguous and are correctly understood. He should also ensure that the answers cover the intended topics. Be careful not to "lead" the respondent.

Structured and semi-structured interviews are a means of obtaining detailed information and opinions from individuals in a group. If necessary, answers can be confidential. They provide reliable information when the views of other group members do not influence the individual.

They are fruitful when it is difficult to get people together in the same place at the same time or when free discussion in a group is not appropriate for the situation or the people involved. It is also possible to get more detailed information in an interview than in a survey or workshop. Any level in an organisation can use interviews.

Considering the ISO 31010 (2019), the strengths and weaknesses are compiled in table 3.2.

3.3.3 Scenario analysis

Scenario analysis refers to a collection of procedures; in which the goal is to develop predictive models.

Overall it involves creating a realistic scenario and calculating what might happen given several likely future events. The methodology adopted to achieve the objective will depend on the time interval, that is:

- **Short periods** - it may be necessary to extrapolate from past events;
- **Long periods** - scenario analysis may mean creating an artificial but plausible scenario and examining the nature of the hazards within that scenario.

Usually, a group of stakeholders with different interests and experiences carries out this assessment. Scenario analysis involves the detailed definition of the scenarios to be assessed. This methodology incorporates an assessment of the impact of the scenario and the associated risks. Commonly discussed changes include:

- Technological changes;
- Possible future decisions with a range of consequences;
- Stakeholder requirements and how these may evolve;
- Macro-environmental changes;
- Physical changes in the environment.

Table 3.3: Strengths and Weaknesses of the scenario analysis technique

Strengths	Weaknesses
- It considers a variety of alternative outcomes. This technique may be superior to the usual strategy of relying on projections that presume future events will likely continue to follow prior trends. This is crucial in cases where there is limited current knowledge on which to base estimations or when examing long-term hazards. - It encourages a wide range of viewpoints. - It supports the tracking of early warning signs of change. - Decisions taken for the identified risks can help create resilience no matter what.	- The scenarios used may lack a solid basis, e.g. the data may be theoretical. This could lead to unrealistic outcomes that are not recognised as such. - There is little evidence that long-term future scenarios will occur.

Scenario analysis is most commonly used to identify hazards and examine their impacts. It can be used at both strategic and operational levels, for the whole organisation or a part of it. Long-term scenario analysis is designed to help plan for considerable future developments, consumer preferences and societal views. Scenario analysis cannot predict the likelihood of such changes, but it can assess the impact and help organisations develop the strengths and resilience needed to adapt to predicted change.

Scenario analysis can predict the evolution of all forms of risk, both threats and opportunities. This technique can examine the impact of an initial event when carried out within a short time frame. Planning for crises or business interruptions are two examples of such applications. When facts are not available, the opinion of experts is a knowledge source. However, the risk manager should carefully examine the justifications for their positions.

Considering the ISO 31010 (2019), the strengths and weaknesses are compiled in table 3.3.

3.3.4 Business Impact Analysis

Analyse the business impact of how accidents and incidents can affect a company's operations and identify and assess the competencies required to manage them. BIA specifically provides information on:

- The criticality of key business processes, functions and associated resources. Nevertheless, also the crucial interdependencies that exist for an organisation.
- Disruptive events will impact the capacity and capability to achieve key business objectives.

- The capacity and capability required to manage the consequences of a disruption. Moreover, the steps needed to return to agreed levels of operation.

Questionnaires, interviews, organised workshops, or a combination of the three are information sources for BIA.

Table 3.4: Strengths and Weaknesses of the business impact analysis technique

Strengths	Weaknesses
- A thorough understanding of the basic processes that enable a company to achieve its goals and identify areas for business development. - Information is needed to prepare a company's response to a disruptive event. - An understanding of the critical resources needed in the event of a disruptive event. - An opportunity to rethink a company's operational processes to improve business resilience.	- The BIA is based on the information and impressions of people completing surveys, conducting interviews or attending seminars. This can lead to an overly simplistic or optimistic assessment of recovery needs. - Group dynamics can affect the overall analysis of a crucial process. - Recovery needs may be either simplified or overly optimistic. - It can be challenging to understand the organisation's processes and activities accurately.

To enable effective planning for disruptive events, BIA is used to identify the criticality and timeframe for recovery of processes and associated resources (e.g. staff, equipment and information technology). BIA also helps identify dependencies and interrelationships between processes, internal and external stakeholders and all links in the supply chain. Ultimately, BIA provides data to assist the business in determining and selecting appropriate business continuity solutions to enable successful response and recovery from disruption.

Table 3.4 compiles the strengths and weaknesses of the BIA techniques.

3.3.5 Risk Register

A risk register collects information about risks to inform people who interact with them and those responsible for their management. It may be in paper form or as a database. Often includes:

- A brief explanation of the risk;
- A statement of the likelihood of the risk occurring;
- The sources or causes of the risk;

- The actions to control the risk.

Table 3.5: Strengths and Weaknesses of the risk register tool

Strengths	Weaknesses
- Risk information is compiled in a format that allows identification and tracking actions. - Risk information is presented in an akin style that allows priorities to be suggested and is relatively easy to query. - The creation of a risk register usually involves a large group and creates a general awareness of the need for risk management.	- Risks documented in risk registers are often dependent on events. An accurate characterisation of some risk types can prove problematic. - The apparent ease of use can lead to false confidence in the information. This problem lies in the difficulty of describing hazards and risk sources. Risks and risk control deficiencies are often misinterpreted. - There are many methods of describing risk. The priority assigned depends on the description of the risk and the level of desegregation of the problem. - Maintaining an up-to-date risk register requires a considerable amount of work. - Risks are often recorded individually in risk registers. This action can make it difficult to gather facts to create a comprehensive treatment plan..

Risks can be classified into numerous categories to make reporting easier. Risks are typically portrayed as distinct occurrences, but interdependencies should also be considered. Risks (the possible implications of what may happen) and risk sources (how or why it could happen) should be documented, as should controls that could fail. It can also serve as an early warning indicator of the imminent occurrence of an event.

Many risk registers also include a rating of the significance of the risk. This rating indicates whether the risk is acceptable or tolerable, whether further action is required, and the reasons for this decision. When classifying a risk as significant based on consequences and probability, the risk manager should consider the possibility of control failure.

Loss of control should be assessed with a risk level, given that it is part of the problem. There is a possibility of documenting risks with positive consequences in the same document as risks with negative impacts or separately. Nonetheless, opportunities are often recorded independently,

and their costs, benefits and potential adverse effects are analysed. A value and opportunity register is the name of this document.

The strengths and weaknesses of the Risk Register technique are compiled in table 3.5.

A risk register is a tool for recording and tracking information about specific risks. This tool has as its objectives:

- Share risk information with stakeholders and highlight significant risks;
- Track risks, controls and actions on corporate, departmental, operational and project levels;
- Provide the compiled information to senior management;
- Track the implementation of planned treatments.

3.3.6 Consequence and likelihood matrix

The consequence/probability matrix, also known as a risk matrix or heat map, is a method of representing hazards based on their consequences and probability. The risk matrix also combines these properties to indicate an assessment of the relevance of the risk. The axes of the matrix represent the user-defined scales for impact and likelihood. Both scales can contain any number of points - the most common are three, four or five - and can be qualitative, semi-quantitative or quantitative. If numerical descriptions define the scale levels, they must match the accessible data and contain units.

In general, each scale point on the two scales must be larger than the one before it to match the data. The consequence scale (or scales) can represent positive or negative outcomes. The scales should be closely related to the organisation's objectives and range from the most to the least credible consequence of interest. Depending on the circumstances, the risk manager can opt between additional or fewer consequence categories, and its scales may contain fewer or more than five points. Words, numbers or letters can represent the consequence rating column.

Furthermore, the probability scale should cover the range relevant to the data. The probability scale may be more or less than five points. The ratings may be in the form of words, numbers or letters. The probability scale should be adapted to the situation and may need to include a different range for positive or negative results. For example, if the highest defined outcome is tolerable with a low probability, then the lowest level on the probability scale should indicate a reasonable likelihood for the highest defined consequence (otherwise, all activities with the highest impact are defined as intolerable and cannot be made tolerable).

When determining the tolerable probability for a single consequence risk, the risk manager should consider that multiple hazards can lead to the same outcome. A matrix is created with

the defined scales on one axis and the consequences on the other. Each cell can be assigned a priority rating.

The design should allow for risk prioritisation based on the extent to which the risk leads to outcomes that do not meet the performance standards set by the organisation for its objectives.

		Impact		
		Low 1	Medium 2	High 3
Probability	Low 1	Low	Medium	High
	Medium 2	Low	Medium	High
	High 3	Medium	High	High

Figure 3.2: Risk Matrix: different weights to impact and probability.

Depending on the application, the risk manager can configure the matrix to define different weights to consequences or probability, as shown in Figure 3.2, or it can be symmetrical. For example, a consequence/probability matrix can assess and communicate the relative magnitude of risks based on a consequence/probability pair associated with a focal event.

Chapter 4

Company Overview

In this chapter, a brief description the company in which the master's dissertation project was carried out, Continental Mabor and its field of activity is presented.

4.1 Continental AG

Continental AG was founded in 1871 under "Continental - Caoutchouc und GutaPercha Compagnie" in Hanover, Germany, as a joint-stock company by nine bankers and industrialists. Initially, the company manufactured flexible rubber parts and solid rubber tires for carriages and bicycles and became known as the "Horse Brand" in 1882.

In 1898, the company began producing car tires. Since then, it has followed developments in the automotive industry to improve tires. In 1904, Continental was the first company in the world to develop "car tires with tread". In 1905, it started producing "non-slip tires with rivets".

In the late 1920s, influential companies in German industry merged to form Continental Gummi-Werke AG. The company produces almost exclusively in Germany, but in 1979 it became an international supplier to the automotive industry and thus began its worldwide expansion.

Today, the Continental Group focuses on the production of brake systems, systems and components for drive and chassis, instrumentation, infotainment solutions, vehicle electronics, tires and technical elastomers. It contributes to more prominent driving safety and global environmental protection. The company is one of the five largest automotive suppliers in the world.

Over time, the company's success has grown from just 200 employees to almost 200000 worldwide. Today, Continental has 13 production facilities in 12 countries, as the figure 4.1 shows, among other investment areas.

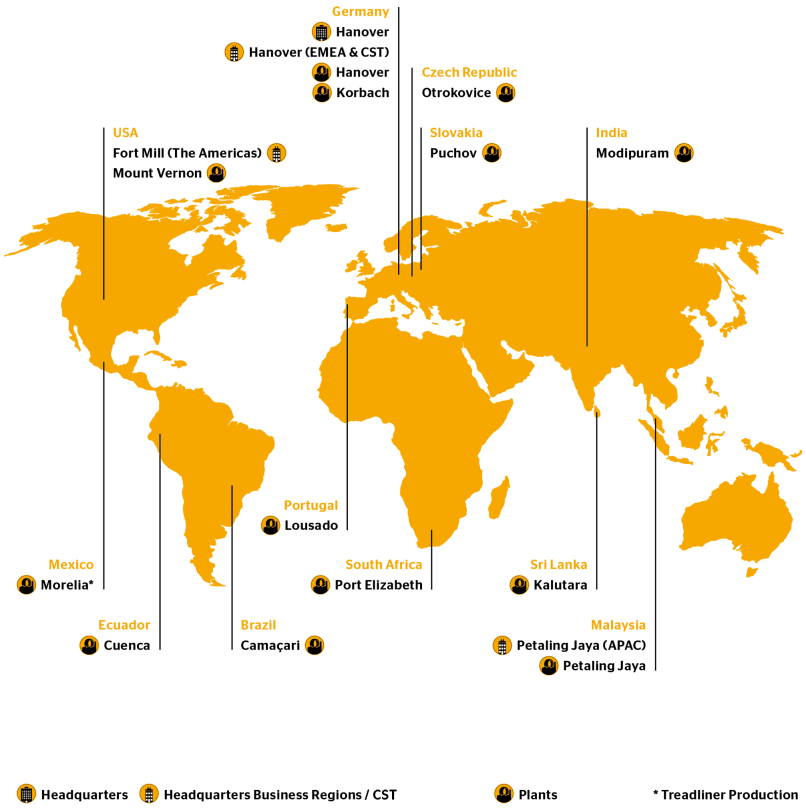

Figure 4.1: Headquarters and plants of Continental AG [Retrieved from (AG, 2022)]

4.2 History and Evolution of Continental

Continental Mabor emerged by acquiring Mabor Manufactura Nacional de Borracha S.A. by Continental AG. In 1989, the acquisition process began when Continental AG acquired 60% of Mabor.

In 1993, the acquisition process was completed, and Continental now owns 100% of the company. Being one of the most significant foreign investments in Portugal to date, made possible by the decisive action of the contracting parties, the support received and the strict adherence to an extensive restructuring program that lasted approximately five years.

Continental AG invested 148 million euros in the former MABOR production facilities during these five years. As a result, CMIP currently has an average production of 58,200 tires per day, compared to the 5,000 tires per day produced by the Passenger and Light truck Tires, PLT, unit in 1990.

During 2016 began the project Commercial Speciality Tires, CST, which allows entry into a market other than the currently covered and previously inaccessible market for tires with particular characteristics, namely tires for use in machinery and agriculture. This factory produces an average of 286 tires.

4.3 Organisational Structure

CMIP, part of the Continental AG group, responds to a central structure with the president and CEO Nikolai Setzer as its maximum representative.

In Portugal, CMIP is managed according to the organisational chart shown in Appendix A. Pedro Carreira is responsible for the manufacturing unit.

4.3.1 Key Users

Implementing corporation information technology, IT, solutions can feel overwhelming, especially for the users, since it is not a small task. After the basic training and the go-live of a system, the application users need support on system usage. The usage includes permissions, functionalities and how they can work quickly and efficiently with the new system.

For each Manufacturing Suite System, MSS, there is a Central Key User, CKU, the contact person on the Business side. Each location assigns a Local key User, LKU, for each system. The LKU is the first contact for application users in their location when having trouble using the system. Also, the CKUs can recommend the best departments to enrol personnel in the LKU function.

Fundamentally, there can be two groups of user questions:

- **Practical questions** (Login, how to handle an application, etc.)
- **Technical questions** (Technical problems within an application or within the system environment)

The Local Key User is also the user who is responsible for working closely with the Central Key User and IT support layer, assisting in the preparation of the methods and the solution test. The Key User should also inform both whenever facing issues and help implement the solution. Figure 4.2 shows the main communication channels from the LKU perspective.

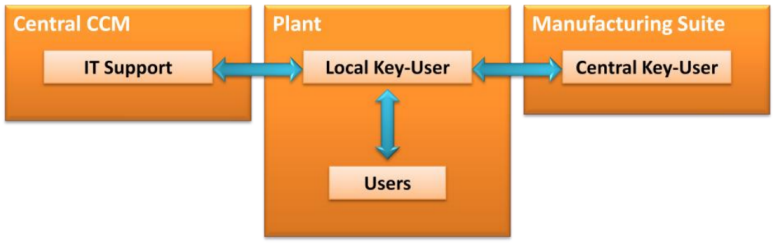

Figure 4.2: Main communication channels from the local Key User perspective. Support is given either on site or remotely by both IT and Central Key User

The Key User would have to be acquainted with details about:

- The business logic within the application;

- The technical integration of all applications;
- The login and navigation within the application.

The Key User has general responsibilities such as:

- Solve functional user questions;
- Create and manage and close the issue and requests list;
- Spread the knowledge in his location and share it within the Local Key User's community;
- Collect technical user problems and address them to the support level;
- Inform users about solved technical problems;
- Summarise user change requests (user suggestions for improvements).

Last but not least, the Local Key User would be actively involved in Conti's communication platforms, accessing the share points for the needed documentation, regularly visiting the Connext platform and contributing with the Lessons Learned during the implementation phase bringing new ideas to the community.

4.4 Mission and Goals of Continental

CMIP's policy is based on its vision. Be a LEADER:

- Efficient Lousado;
- Innovates and anticipates customer needs;
- Develops high technology products;
- Excellent in knowledge and processes;
- Profitable on a sustained basis.

The organisation's policy is also based on the values of the Continental Group, which are:

- Trust;
- Passion for winning;
- Freedom to act;
- For each other;

4.5 Quality Management System

CMIP's QMS is defined and implemented to ensure all the activities of conception and development, fabrication, commercialisation and assistance after the tire selling. Figure 4.3 shows the CMIP's QMS.

For better categorisation and management of the QMS, each process that is part of it should be categorised as one of the following:

- **Management Processes** - refers to processes which set goals, plan and control the organising and leading the execution of the value-adding processes and supporting processes.
- **Value Adding Processes** - refers to processes that transform raw materials or semi-finished products into more valuable goods and services to customers downstream.
- **Supporting Processes** - are all processes whose sole purpose is to ensure the functioning of value-adding processes and overall operations of the company.

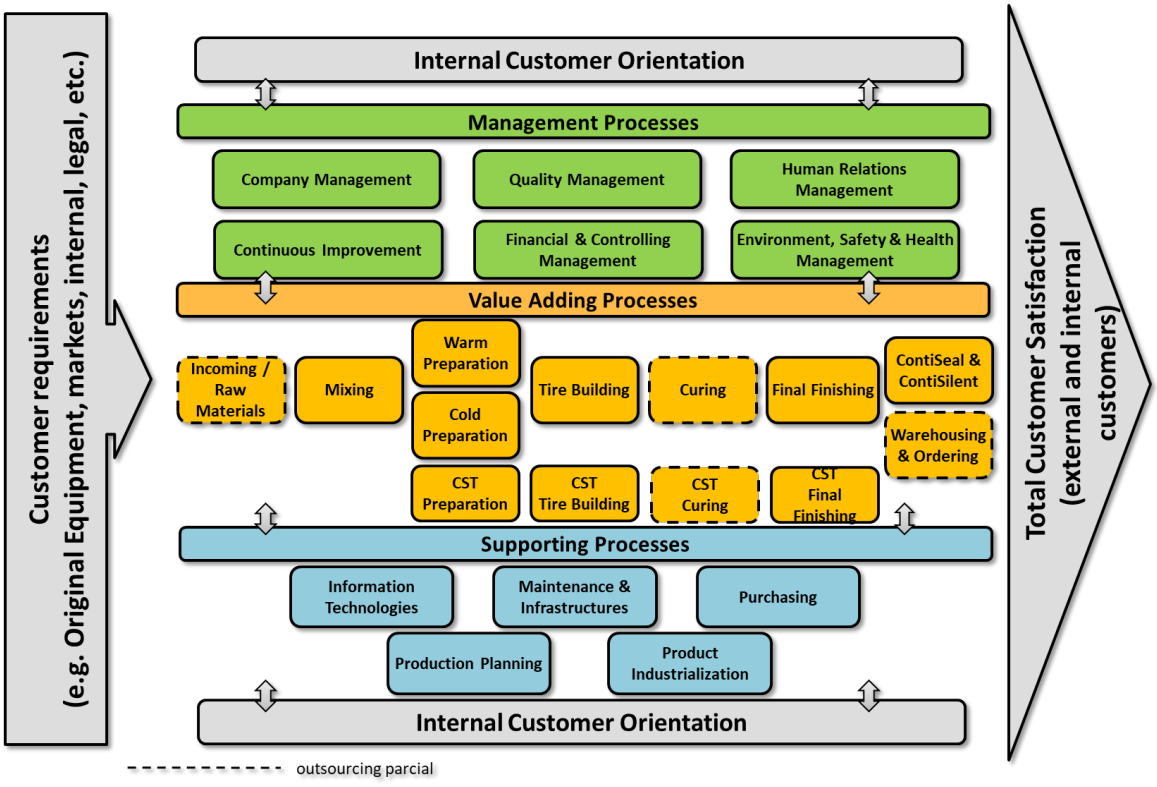

Figure 4.3: CMIP's Quality Management System

The following sections describe the value-adding processes in greater detail for a better understanding of the production process and the role of the supporting process, Information Technologies.

4.5.1 Product Process

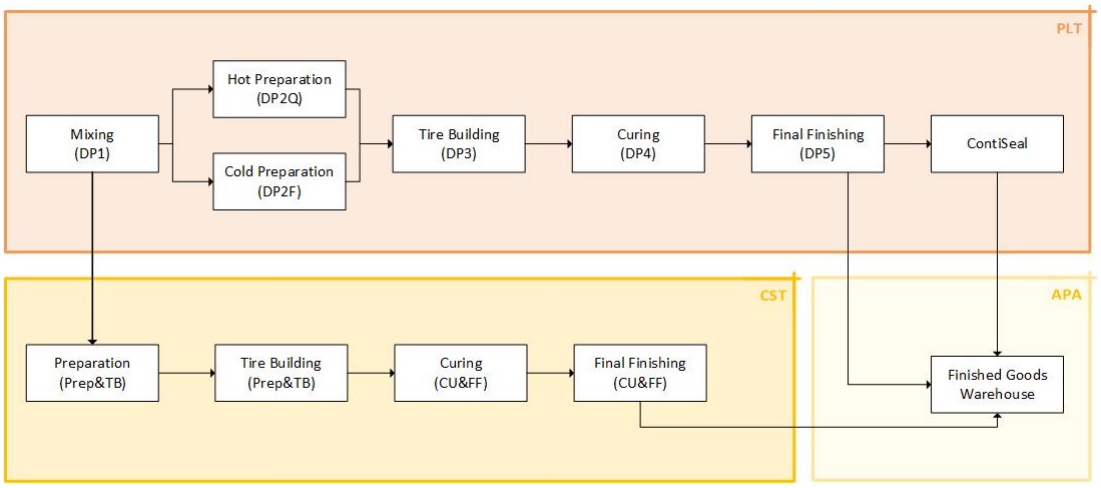

Figure 4.4: Product Process

This section contains a small exposition of the Value-Adding Processes that continue the CMIP production system. As previously described, CMIP divides into two manufacturing units, PLT and CST, and the production process is quite similar in both units, as seen in figure 4.4. However, the CST manufacturing unit has four distinct phases ensured by two departments.

4.5.1.1 PLT Unit

The PLT factory has five distinct phases ensured by six departments (figure 4.5). The manufacturing systems always support production.

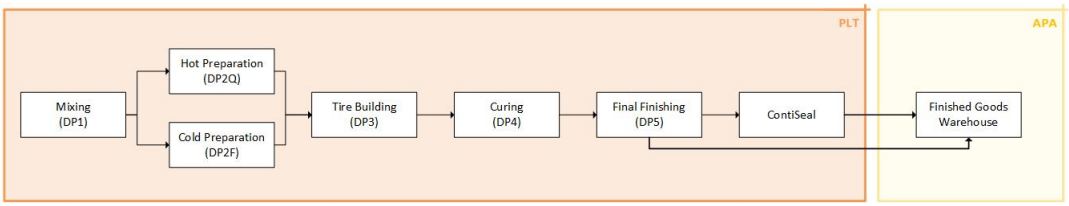

Figure 4.5: PLT: Product process chart

Receipt of Raw Materials

Like any other company, CMIP needs raw materials to produce. The suppliers have a close connection with the company, which translates into reduced safety stock and periodic deliveries. Depending on the item, these deliveries can happen several times a day, a few times a week or a month.

Phase I - Mixing

The mixing department, figure 4.6, is responsible for producing compounds, commonly known as rubber. Some raw materials are mixed here, such as natural rubber, synthetic rubber, pigments, mineral oil, and silica, among others. The pigments, too, are pre-mixed through recipes at an early stage.

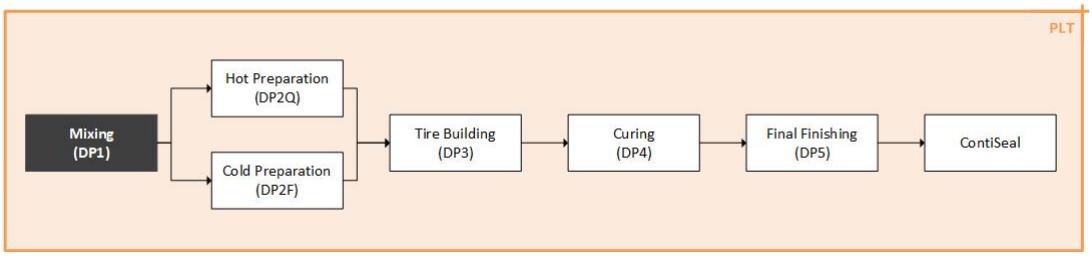

Figure 4.6: Phase I - Mixing

Two types of compounds come out of this department, the Masters and the finals. Masters originate from the mixture of rubber, oils and chemicals. The finals are the Masters, where chemicals are again added to give it a set of specific characteristics. The final compound serves as raw material for the following departments.

Phase II - Preparation

At this stage, the very name Preparation illustrates what will be accomplished here. All the components that will integrate the tire in the construction are prepared. This phase is subdivided into two departments, DP2F - Cold Preparation and DP2Q - Hot Preparation, see figure 4.7.

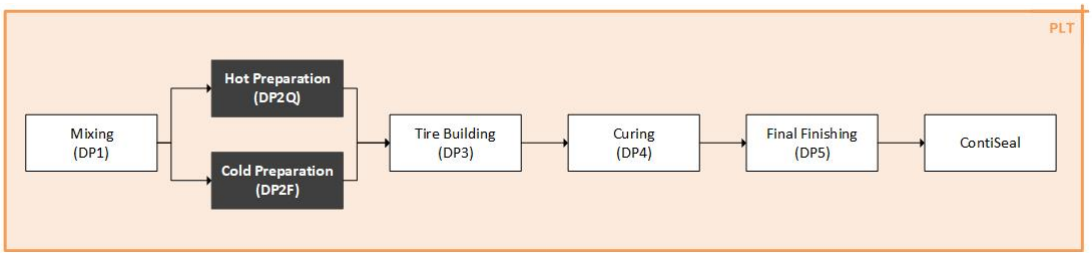

Figure 4.7: Phase II - Preparation -

The Hot Preparation produces the floors, walls, wedges and beads. The Cold Preparation produces waterproof layers, textile fabrics and reinforcements. All semi-finished products are transported by floor trolleys or cassettes to the construction area.

Phase III - Tire Building

In the so-called Karcass Machine (KM) and Pressure Unity (PU) Construction Modules, all components from the Preparation are assembled in a phased manner, giving rise to the semi-finished "Green Tire". This process occurs in the Tire Building department, figure 4.8

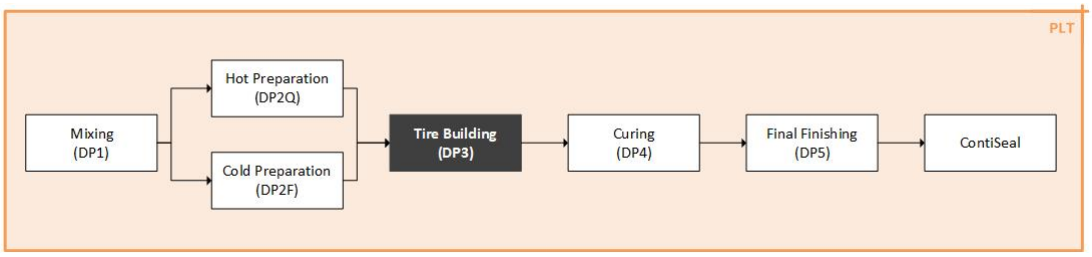

Figure 4.8: Phase III - Tire Building

In KM Modules, the tire carcasses are produced using beads, the waterproof layer, and the textile fabric that passes through an uneven track to the PU Modules, where the Breakers, textile belts, reinforcements, walls and the floor are added. The green tire goes through automated treadmills to the following department.

Phase IV - Curing

The Curing Department is subdivided into two, Painting and Curing (figure 4.9). Painting is the step where the green tire receives a bath on the inner wall of an emulsion. After this stage, it is stored and transported in carts to the presses.

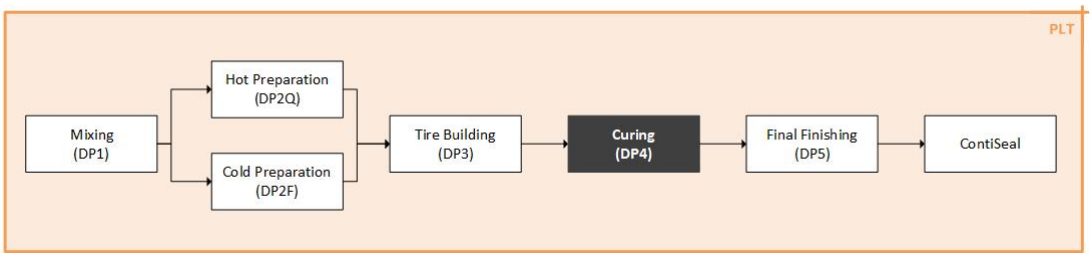

Figure 4.9: Phase IV - Curing

In the Curing stage, the green tire is placed in a diaphragm, which cycles water vapour at a high temperature. The mould closes over the tire in green, and tire curing occurs. The mould has an embossed pattern. This pattern will be engraved on the floor, and the inscriptions to be placed on the wall.

Phase V - Final Finishing

This department checks all the tires produced to ensure all tire quality requirements (figure 4.10).

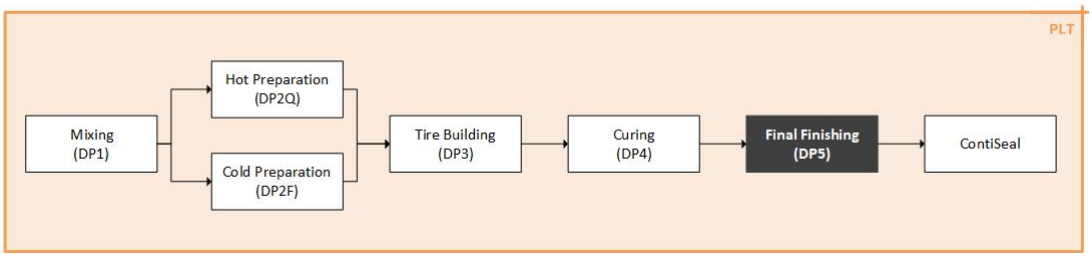

Figure 4.10: Phase V - Final Finishing

Firstly, visual checks are conducted by operators that certify the quality at the level of text and appearance defect. Then, a later phase through equipment, testing the physical properties like geometry and balance.

After this phase, the tires go to the finished product warehouse.

ContiSeal

At this stage (figure 4.11), the ContiSeal technology is applied to the tire, a viscous and adherent sealant layer that coats the inside of the tire's tread.

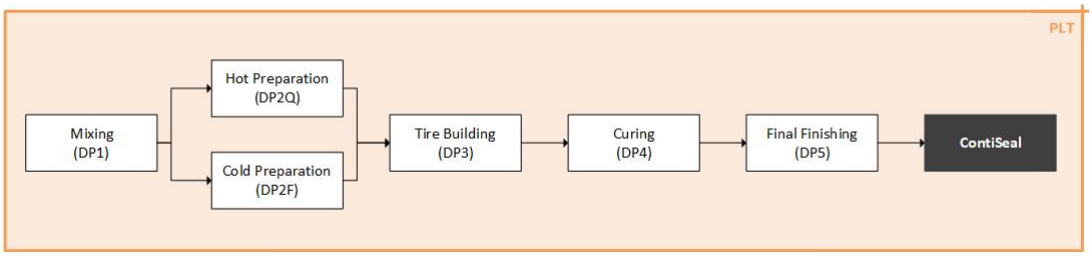

Figure 4.11: ContiSeal

Armazém de Produto Acabado (APA)

In this business unit, the tires are stored on metal pallets until it is necessary to satisfy the orders of the different customers, whether national or international.

4.6 Description of the Manufacturing Execution System

This section will present the Manufacturing Execution System (MES) in detail. All the systems and applications that compose the MES and other supporting systems are on one of four levels, being those:

1. **Central**: system-related logistics, recipes and specifications.
2. **Plant level**: all systems and applications control the data and operations inside the plant.

3. **Industrial PC (IPC) level**: each machine inside the plant is integrated into this level. Each is a client to the previous level.

4. **PLC level**: because of all the different types of machines, the previous level is more generic, and this one will do the translation between the generic and the language of each machine.

Appendix B.3 shows the data flow of the communication between the MES systems and supporting systems.

4.6.1 CGMS

The Conti Global Manufacturing System, CGMS, is the new manufacturing execution system and covers, at the moment, the Preparation, Tire Building and Curing area among the production stages. It aims to provide current and accurate information about production activities across the shop floor and communication to the enterprise level. CGMS replaced the Shop Floor Integration, SFI, system, which suffered from historical growth and disproportional support demand.

With the introduction of CGMS and Continental Standard Machine Interface (CSMI), the standardisation of software happened. CGMS has as core functionalities:

- Order Processing;
- Material Validation;
- Machine Operation;
- Tooling Validation and Tracking;
- Recipe Validation;
- Genealogy Tracking and Traceability.

CGMS introduced other benefits and improved others, as follows:

- **Operator Screen**: this is the visual part of CGMS where the shop floor operators interact. It is a Windows application that runs on the machine and is accessible from the machine's screen. The operator can access various user tabs on the machine as counts, orders, losses, material, tooling, charts and alarms.
- **Counter over and under production warnings**: A production counter is displayed on the CGMS screen. The counter will indicate the quantity produced at the machine and then compares this to the order target (e.g., meters of sidewall or number of tires). The count information transfers to the CGMS manufacturing dashboard website, where the machine performance can be monitored live.

- **Losses and loss reclassification**: losses are a way of managing/recording what is happening at the machine, i.e., why the machine is not operational (e.g., breakdown, lack of components, low efficiency). The current loss is easily selected from the CGMS operator screen. In addition, losses can be quickly reclassified on the CGMS Operations website.

- **Recipe Management**: recipes are sent directly to the machine from the recipe management system, CGRS. A valid recipe must be available for the machine to run "automatically". The recipes can be fine-tuned at the machine, with either operator offsets or technician offsets.

- **Manual Orders and SAP Orders**: Manual orders can also generate right at the machine. Given the availability of a recipe, it is important to note that the manual order will not give any feedback to SAP and fulfil the stock levels. Orders sent to the machines from SAP are visible in the Orders tab on the machine's screen (CGUI - Client User Interface).

- **Alarms, SMS, Emails, and Notifications**

4.6.2 MMS

MMS or Manufacturing Mixing System is the equivalent of CGMS to the Mixing area. This system provides current and accurate information about production activities across the shop floor and communication to the enterprise level. MMS permits a complete visualisation, control and manufacturing optimisation. MMS's main features are:

- **Order execution**: providing the user several KPIs, such as order state (for example, is order is in production, postponed, or other); produced quantities (near real-time machine counts); order efficiency and others.

- **Material Validation**: before starting production, MMS conducts a series of validations: consumer material, used tooling, machine recipe and operator (authentication and authorisation).

- **Genealogy**: MMS maintains links between produced and consumed parts; checks materials against BOM from the specification. Furthermore, it provides material tracking and tracing (where, who, and on what machine; were stored/consumed).

MMS is in strict communication with LABsystem, sending the information of each lot to it. LABsystem will process it and return to MMS the quality status of each lot.

4.6.3 MCAT

MCAT stands for Material Control and Traceability, is responsible for tire control, tracing, and tracking and provides an interface between enterprise, plant and shop floor levels.

4.6.4 EWM

SAP EWM stands for Extended Warehouse Management. It manages lots and carriers movements, ensuring that the correct Input Material has been delivered to the correct production machine, from Preparation to the Curing area. Additionally, its current implementation maintains stock information, i.e., all lots and units being produced, to have higher accuracy for auto-replenishment calculations. The main functions of EWM are:

- Stock control on carrier level (accurate stocks);
- Securing of First Expired First Out, FEFO, (Quality Requirement);
- Material flow control (guiding of the transporter);
- Optimised routing of transporters;
- Reduction of unloads drives.

4.6.5 CGRS

The CGRS, Conti Global Recipe System, is a recipe management system which assures recipe values from the specification system THERMO down to the shop floor into the PLC. CGRS is implemented in the plants and integrated with the CGMS manufacturing suite. It handles the recipes for all production machines in Preparation, Tire Building and Curing.

The main principle behind CGRS is the correct control of machine recipes. It ensures that the right recipe is used, e.g., to cure a tire, and deals with the diversity of parameters. CGRS is easily accessible for end-users and allows fast development of recipes for the machines. Furthermore, it is more flexible to add or change new recipe parameters. The implementation of CGRS improved access control and allowed single sign-on functionality.

4.6.6 FFDACS

FFDACS or Final Finishing Data Acquisition and Control System ensures the verification of the quality status for every tire produced in Lousado. It controls the following machinery:

- Tire Uniformity;

- Tire Geometry;
- Tire Balancing;
- High Speed Uniformity;
- Tire Marking.

FFDACS has as core functionalities:

- Recipe management;
- Results storage;
- Reporting;
- Machine control;
- Optimisation and Cpk stop check;
- Alarming.

Chapter 5

Methodology

As stated in Chapter 4, this case study demonstrates the use of a risk assessment in the CMIP. Schematic 5.1 depicts the steps contributing to the recommended strategy's achievement.

The implementation of the risk assessment tools required some preliminary steps. As shown in the figure 5.1, the steps include meeting with the key elements of each department, understanding the process that would be studied, analysing the organisational context of the CMIP, analysing the risk assessment process developed at CMIP between 2012 and 2014, defining the techniques to be used, and defining the risk management process, as well as its execution.

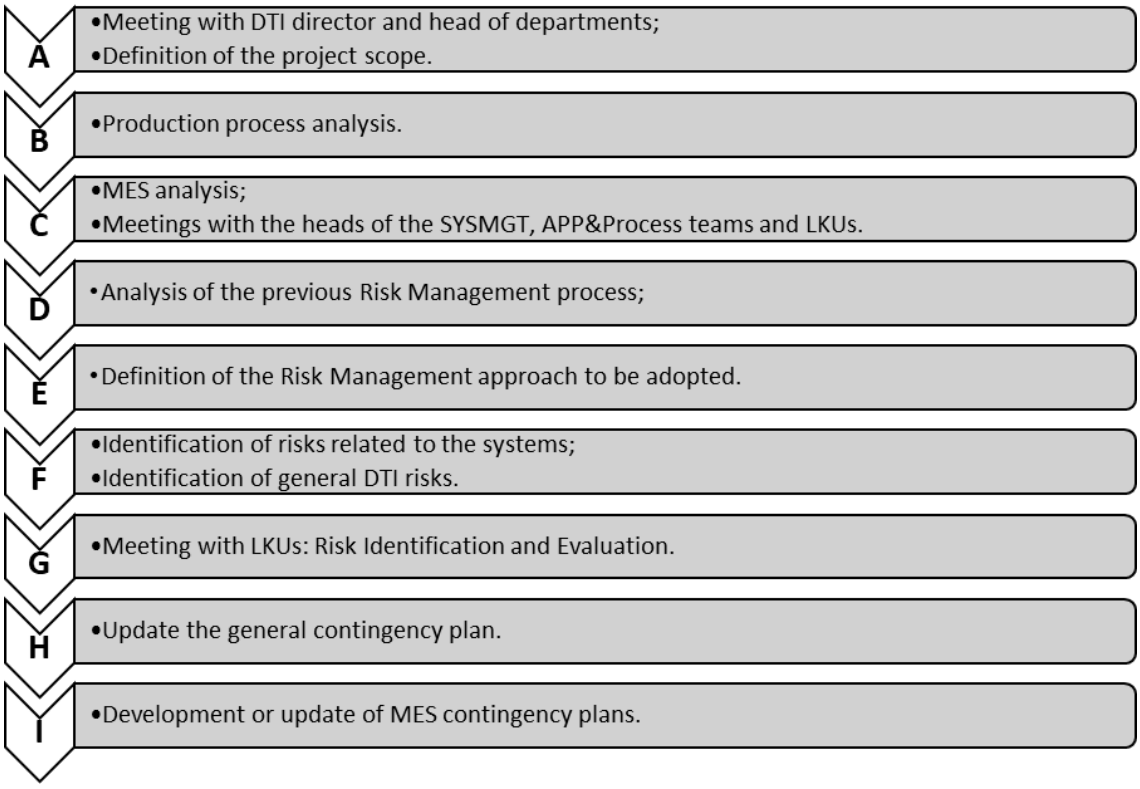

Figure 5.1: Risk Management Methodology Stages

5.1 Stage A - Scope, Communication and Consultation

Building a well-versed team in the manufacturing process is required to complete the risk assessment efficiently.

To properly execute the risk management technique, it was necessary to communicate with the several CMIP directions. As a result, a determination of which elements should take part in each stage of the process was made.

During this initial phase, the scope was established as the MES risk analysis from an IT perspective, ignoring failure due to human mistakes, mechanical failure, or minor accidents affecting only one machine. Because of the criticality and significance of the risks in the business sense. The criticality in a single scenario like those discussed would always be minimal, given that the corporation should try to secure 40% of its production (Original Equipment (OE) clients).

Meetings were held with the heads of each production department to better identify and analyse risks after setting the scope. In addition, each department manager described the manufacturing process and updated the process mapping.

To provide a clearer understanding of the MES was necessary:

- Discuss with the Applications and Processes team;
- Organise an interview with the Infrastructure team.
- Interview each LKU;
- Examine the documentation for each system.

The consultation with the department heads and the *Direção de Tecnologias de Informação* (DTI) director was essential to achieve stages D to F.

Meetings were held with the respective LKU to carry out the risk assessment after collecting the information in stages B, C, and G and defining the risk management approach in stage E.

It was crucial to forming multidisciplinary teams to complete stage H, their composition changes depending on the system in the issue.

The best sources for acquiring information were investigated during every stage while keeping the scope of the risk assessment in mind. The following sections will address in further detail steps B through I.

5.2 Stage B - Production process analysis

The primary goal of this stage was to learn about the actions that occur during the manufacturing process. As a result, it was necessary to study the paperwork provided and conduct a series of follow-up visits to the two CMIP units: PLT and CST.

Production is the part of the business that has the most QMS processes, employs the most people, and earns the most income. The production process is the process that produces the various types of tires. Section 4.5 details the manufacturing process in CMIP.

A colleague from DTI made the initial visit and detailed the complete PLT and CST manufacturing process. The laboratory manager conducted the visit to the laboratory, while in ContiSeal, a process engineer was the one presenting the department. These visits were an opportunity to:

- Ask questions regarding the stages of the production processes;
- Identify and understand the risks to which the company is exposed;
- Which mechanisms to activate in case of failure;
- The impacts of the MES on production in case of failure;
- Establish a basis for defining actions that mitigate the MES impact.

5.3 Stage C - MES analysis

Given the inter-connectivity, a study of the MES was carried out concurrently with the manufacturing process analysis (section 5.2). Section 4.6 defines the MES's composition in terms of the functionality of each system and its relationships. This topic examines the interaction between the MES and the manufacturing process.

The figure 5.2 depicts an example of what was discussed previously in section 5.1, during meetings with department managers and the process mapping update.

<table>
<tr><td>With:
- Local and central software available (SAP, ıCAT, CBDAS, FFDACS, MS Office)
- Transport and palletizing equipment
- Auxiliary equipment for tire inspection
- Uniformity and balancing equipment
- Marking and validation equipment
- Tire refinishing equipment
- BCD and scraping equipment (tire correction)
- Tooling
- Computer and communication equipment
- Storage areas
- Monitoring and measurement features</td><td colspan="2">Client of:
- Quality management
- Human Relations Management
- Continuous Improvement
- Safety, Health and Environment Management
- Raw material
- Curing
- Information Technologies
- Maintenance and Infrastructures
- Purchasing
- Production Planning
- Product Industrialization</td><td>Supplier of:
- Warehouse and Shipping
- Product Industrialization</td><td>With whom:
- Final Finishing Department Manager
- Supervisors
- Qualified operators
- Technical Support</td></tr>
<tr><td rowspan="2">Inputs:
- Cured tires
- Maintenance plan
- Production plan
- FMEA
- Specifications
- Approved touch-up compounds</td><td colspan="2">Goal:
Ensuring delivery to the warehouse of inspected and tested tyres with defined efficiency and quality.</td><td rowspan="2">Outputs:
- Inspected and tested tires</td></tr>
<tr><td colspan="2">Manager:
Final Finishing Department Manager</td></tr>
<tr><td>How:
- Company Politics
- Central PoMS documents
- Local PoMS documents:
(EX: Control Plan, WI, Procedures, etc.)
- Revenue management
- Stock management
- Product or process data management</td><td colspan="2">The Risks are identified in the FMEA's of the process:
- FM -0022.

Opportunities:
- Layout with optimised and automated flows
- Implementation of new technologies (AutoClass and CMS)</td><td>KPIs:
- Yield Slow Movers OE Warehouse
- Total Complaints (OE+ MS)
- OEE Uniformity
- Tires Delivered</td></tr>
</table>

Figure 5.2: Mapping Process: Final Finishing example

In addition to the information collected during these meetings, it was also necessary to meet with the:

- LKUs for a better understanding of the systems (functionalities, interconnections and production support);
- SYSMGT team to understand what are the communication exchanges between systems and the support infrastructures; and
- APP and Processes team to consolidate all the information.

Schematics in Appendices B.2 and B.1 resulted from this collection of information. Both schematics represent the distribution of systems per department, the infrastructure between them, and the data transfer between departments and systems.

Considering the resemblance between the PLT and CST manufacturing units in terms of interaction between the MES and the production process, the case of PLT will be exposed in the following topics, referring to the differences present in CST.

The process starts with the Mixing (DP1 in PLT) for both plants. Initially, the MMS receives information regarding the revenue of the compounds to be produced from CBS3. Then, the MMS manages the orders allocated to each mixer. Finally, the operator initiates the order in the mixer and starts the production process.

LABsystem supports the periodic testing of the compound during its production. There is an exchange of information between MMS and LABsystem. MMS sends the compound in production information to the LABsystem, while LABsystem evaluates the quality status and provides this information to the MMS. If the quality status is ok, the operator receives a printed green label with the data of that lot. Otherwise, it will be a yellow label. After the production of the compound, the CGMS receives the mixing data via Data Integration Layer, DIL. Then, the lot rests for a certain period before being consumed in DP2.

From DP2 to DP4, the MES macro process is transversal, i.e. there is a cycle of interconnections between systems that is the same in these departments, as can be seen in diagrams in Appendices B.2 and B.1.

The next stage begins in DP2 after the compound resting period.

CGRS manages recipes; as a rule, every machine possesses all recipes for semi-finished items. For the operator to begin a new order, it is necessary to carry out its planning in SAP PP, which sends the orders to the CGMS and ensures all actions related to production management.

All IPCs have a visual interface with the operator, where he can choose the order, and the GUI provides the necessary alarmistic in case of failure. After selecting the order, the operator validates the materials and proceeds to manufacture the semi-finished product. After its production, EWM receives a posting. EWM manages the stock of that product and the products consumed for

its manufacture. EWM informs SAP PP of stock changes, so Scheduling can adjust the order schedule and send them to CGMS.

The process in DP3 is quite similar to DP2. Only differ in the last stage of the process, after the green tire production, CGMS sends the bar code information to MCAT. The same happens in DP4 in two instances: after spraying and after the curing process.

After the production, all tires go through the inspection process, DP5. As previously mentioned, the MCAT received the bar code information in DP3 and DP4 from the CGMS.

The bar code information permits MCAT to manage the tire transport system between DP4 and DP5, as within DP5. Every tire goes through two inspection stages. In the first phase, the graders inspect the tires using Grading. In this system, they assign the classification to each bar code inspected. If the tire is ok, it proceeds to the automatic verification process that relies on the FFDACS. If the quality checks are ok, the operators prepare the shipment to APA or ContiSeal through eLISA. In the case of CST, the production process ends at this stage.

However, for some PLT tires, the process can have one more step. ContiSeal receives a tire shipment and proceeds with the application of Silent or Sealent. In this department, the systems involved in production are:

- eLISA - assists the operator in receiving and dispatching tires to the department;
- MCAT - controls the transport system used in the department;
- Grading - as in the DP5, they assist in carrying out the tire inspection;
- CGRS - controls spraying recipes;
- CBDAS - assists in the counts and production of each machine;
- SAP PP - order creation.

Currently, engineering systems support the production process in ContiSeal, but the roll-out of CGMS has begun.

5.4 Stage D - Analysis of the previous risk management process

It was required to investigate the prior strategy to risk management by IT to evaluate and attempt to incorporate the approach adopted by Continental AG.

Continental's headquarters launched a project named "Risk Management IT Shop Floor Systems" in 2012. This project arose due to the management team's heightened awareness due to the increase in outages, the rising reliance on IT shop floor systems, and the integration of the

whole system landscape. As a result, the steering committee established the following requirements:

- **Business Assessment**
  - Identify the most critical systems and interfaces;
  - Definition of outage scenarios for major risk areas;
  - Risk analysis on shop floor IT failure using FMEA approach;
- **Mitigate Risk**
  - Define measures for processes, emergencies, action plans;
  - Define procedures to reduce the business impact of failures;
  - Define actions to reduce the probability and duration of down times;
  - Define the process for planned maintenance of IT systems;
- **Integrate Measures**
  - Rank measures in the effort, cost, benefits and provide a roadmap;
  - Identify organisation needs for appropriate support;
  - Proposal to establish risk management shop floor IT as an organisation.

Since these objectives are broad and may encompass many systems, Steering has defined the scope of this project, which includes:

- Manufacturing Suite Systems, Globally Unified Tire Specs (GUTS), WAMOS and interfaces;
- IT failures (hardware, software and data).

Given the wide scope of the items, it was also essential to not include:

- Spare parts management;
- Business processes re-engineering;
- Replacement of standard systems;
- Implementation of defined measures;
- Natural disasters;
- None IT-related external reasons.

As a result, to meet these requirements, data collection was carried out at each plant, including the risk identification and analysis stages of the risk management process. The Steering Committee outlined the application of the Business Dependency Analysis (BDA) and Failure Process Matrix (FPM) methodologies. Their goal is to analyse the risk of substantial losses in cost and quality. The steering team defined the crucial processes and IT services for pilot evaluations, and Lousado participated in those assessments.

The goal of the steering committee was to conduct the business assessment in three modules:

1. Business Dependency Analysis for two dominant processes;
2. Business Dependency Analysis for all systems in scope;
3. Failure Process Matrix for processes, systems and interfaces for all critical systems.

The procedure of carrying out the BDAs was transparent; they were carried out for the overall manufacturing process and each system within the scope. In the first instance, the Process BDA was performed to assess the influence of the MES on the production process on a macro scale. The Process BDA included two interviews with the plant's senior management for Production and Plant Operations. Both BDAs examined IT reliance, which involves determining the moment in time when substantial monetary losses can occur per day. Lousado chose to perform only one BDA, combining Production and Plant Operations due to their interdependence.

In a second instance, the BDAs were conducted for each system specified by the Steering Committee with the following goals in mind:

- Assess dependencies of critical business processes per IT system;
- Show the main functions of critical business processes per IT system;
- Tell about the risks in the production;
- Determining "Recovery Point Objective" and "Recovery Time Objective";
- Give valuable information about possible manual workarounds;
- Allow filtering of the FPM process to the most critical systems.

Each BDA required the assignment of a multidisciplinary team to each system.

Following the completion of the BDAs, an FPM was conducted for each system (example in figure 5.3). The resulting FPMs were generated during focused interviews with experts (process manager, department manager, IT service provider, LKU) of the process and the IT system. The systems in the scope of this project were:

- TICS;

- SFI;
- SAP PP;
- MCAT;
- Grading;
- FFDACS;
- WAMOS

Continental Information Technology

Critical Business Processes

SFI 1.0 Lousado

			Scanner	SFI-PC	IPC	⋮	⋮	LAN	WLAN	WAN	SFI application / server	TICS Interface	Spraying Interface	GT Conveyor System Int.	SAP XI	SAP PP P20
		LDC breakdown cost for workplace per hour within TTR:														
		LDC breakdown cost for workplace per hour out of TTR:														
		Probability of failure occurence:														
No.	Process	Process risk / Distinction of cases	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
		Total:	3	4	53	0	0	0	0	0	0	1	1	1	17	40
01	Greentire Scrap															
02	GT assignment to the BC		3		3										1	
03	Order handling				25							1	1	1	8	20
04	Production Counts				25										8	20
05	Operator ID Management															
06	Tire BC scan															
07	Reporting			4												

Figure 5.3: Failure Process Matrix. In the image the blue columns represent the interface and hardware of Engineering responsibility, while the yellow ones represent the Local IT responsibilities and the orange the ones from Central IT

This assessment resulted in seven BDAs and FPMs related to the systems. Another result of the assessment consists of three MES contingency plans and one general contingency plan that will be discussed later in sections 5.7 and 5.8.

5.5 Stage E - Definition of a risk management approach

The previous section presented the methodology used in the Risk Assessment between 2012 and 2014. Since there were no new guidelines for the Central, several changes were proposed to the DTI to carry out the new risk assessment and its documentation.

In this new assessment, the structure followed was the one proposed by the ISO 31000:2018 standard, figure 5.4.

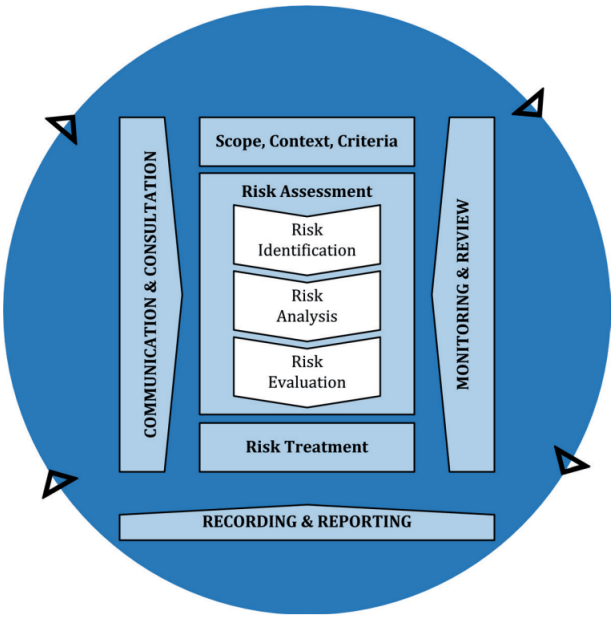

Figure 5.4: Risk Management Approach to be applied in MES Risk Assessment. (adapted from (ISO, 2018b))

Initially, the scope of the Risk Assessment was defined together with the DTI. The systems in the scope of the Risk Assessment are:

- CGMS;
- CGRS;
- EWM;
- FFDACS;
- MCAT;
- MMS.

After defining the scope, the methodologies to be applied during the risk assessment were defined. For each of the Risk Assessment phases, the following techniques were used (explained in section 3.3):

- **Risk identification**: Business Impact Analysis, Scenario Analysis, Semi-structured interviews and Brainstorming;
- **Risk Analysis and Risk Evaluation**: Risk Register; Structured interviews and consequence and likelihood matrix.

Section 5.6 presents the Risk Assessment process in more detail. One of the core stages of the Risk Management Approach is Communication and Consultation. As a result, the DTI was notified of all developments throughout the Risk Assessment process. For each previously mentioned system, a Risk Register and a Risk Matrix resulted as deliverables of the assessment.

After conducting the Risk Assessment, the next stage was Risk Treatment. The creation of contingency plans for each of the Risk Assessment target systems happened in this stage (section 5.8). Section 6.3 shows the results of the risk treatment.

5.6 Stages F and G - Risk Assessment

The previous section discussed the new risk management approach and its scope. However, in parallel with the risk assessment directed to the systems, it was asked to carry out the risk assessment of the general IT to include these points in the CMIP's general contingency plan. In order to carry out this Risk Assessment, the items previously included in this plan were reviewed with DTI management during general contingency plan review meetings. Section 6.2 presents the results of this assessment.

In parallel with the risk assessment for the CMIP contingency plan, the risk assessment was conducted for the systems defined in 5.5. Therefore, meetings were initially held with the LKUs. These meetings' goal was to understand better the system assigned to each LKUs and their role in the MES. In an initial phase, the meetings were based on the BIA methodology (section 3.3) to understand the system's interdependencies to be evaluated with other systems and thus carry out an impact assessment. Afterwards, meetings were held with the directors of each department. Their goal was to understand the interconnections and impacts of the systems in their departments. Finally, the information was documented in a risk register for each system.

After organising the different risk registers, they were presented to the respective LKU. Finally, the Risk Evaluation process was carried out together with the LKU. Section 6.1 shows the results of the risk assessment.

As discussed in 6.1, together with the LKUs, contingency measures were defined in the event of risks. Preference was given to creating contingency measures instead of preventive measures since the objective will be to guarantee the business continuity each risk occurs.

After filling out the Risk Registers, the corresponding risk matrix for each one was created to help visualise the risks.

5.7 Stage H - General Contingency Plan

In 2014, the DTI created a global document where all points related to the contingency plans would be exposed, thus condensing all the information in just one document.

One of the objectives of this dissertation work was to update this document. This update guaranteed response to the changes to the IATF and its sanctioned interpretations. So it was necessary to analyze IATF 16949, analyze the changes from 2014 to 2021/2022, and understand the necessary changes to the document. After this analysis, a proposal was developed and presented to the DTI management, including the DTI manager and the three department leads.

The update process needed three meetings to present and ensure that the last proposal answered the changes in the IATF. Therefore, the agenda of the first meeting included the presentation of the IATF changes and the definition of the contingency plan structure.

The defined structure of the general contingency plan is:

1. Objectives
2. Scope
3. Responsibilities
4. Definitions
5. References
6. Description
7. Records
8. Revisions
9. Attachments

This document's objective was to describe the functional aspects of the definition and implementation of contingency plans resulting from the unavailability of computer systems. Its scope includes processes where the contingency situation results from significant impacts on the processes and products due to the unavailability of manufacturing systems.

Then, the responsibility for activating the contingency plan is either the DTI director or a substitute designated by him. Next, the Contingency Plan Matrix defines the responsibility for the internal or external actions during the contingency or recovery actions. Finally, the responsibility for the training process, simulation and review of contingency plans rests with the person in charge of the process that is the object of the contingency plan.

The definitions of several acronyms in the document were added in the Definitions section to clarify and make the document easier to read. References concerning documents that reference this one was also added in the References section.

The following section divides in:

1. **General description** - This section sets out the requirements of the IATF and Continental AG, such as:

   - The annual review of the contingency plans or when changes are made to the processes covered by the contingency plans. These reviews should include elements from the DTI, Manufacturing Technology Engineering (MTE), *Direção de Qualidade* (DQ), *Direção de Engenharia de Produção* (DEP) and *Direção de Produção* (DP), and other areas that may be relevant to the process under analysis.

   - Simulations to assess the effectiveness of contingency plans will be carried out whenever there is availability and their conclusions may trigger a review of the contingency plans.

   - The training of those involved in the communication chain of the processes that are the object of the contingency plans will be administered whenever there is a new contingency plan or a significant change to an existing one.

   - Documentation of the review of contingency plans, training and simulation.

   - Conducting audits by Qulity Management (QM) Local, QM Central and the IATF certification body.

2. **Aspects to be observed in a contingency situation** - in this section it is mentioned that during the contingency situation, the organisation must ensure for all materials produced and consumed:

   - identification;

   - traceability;

   - validation;

   - compliance with Legal and Customer requirements, as determined by the Procedures, Work Instructions and Specifications in force.

3. **General rules for contingency plans** - the description of the structure of the contingency matrix is performed (see section 6.3) ;

4. **Processes with contingency plans** - the list of processes/systems/infrastructures with contingency plans is displayed.

The agenda of the second meeting was the presentation of the proposal for the new version of the general contingency plan. After reviewing the proposal, the DTI director asked about the possibility of reviewing the document with the DQ. To ensure that both the IATF and the Continental requirements were met. After this evaluation, the last meeting was held to validate all the amended points, and after reaching a consensus, the general contingency plan was submitted to PoMS (Process oriented Management System) for approval by all CMIP directors.

5.8 Stage I - MES Contingency Plans

As stated in section 5.4, three contingency plans resulted from the Risk Assessment conducted in 2014. Therefore, the two phases required to establish the updated contingency plans were reviewing the already defined contingency plans and creating new ones.

For both situations, it was necessary to establish multidisciplinary teams, which must integrate elements from all affected directions in case of a system failure to be covered by the contingency plan. Therefore, the multidisciplinary team proposal was created prior to the first meeting. The proposal was then presented in the first meeting, where the need to integrate more elements was evaluated.

Developing a damage scenario for each contingency plan was necessary to contextualise the multidisciplinary teams. Each damage scenario should show which areas are affected, impacts in other areas, and impacts on other systems, among other relevant points.

In the case of revisions to the contingency plans, it was necessary to update the information on the numbers related to production; review which procedures present in the contingency plans are outdated. After the operation of these two actions, the new contingency plan proposal was presented to the team. Then, the proposals were discussed with the teams until they could reach a consensus among all the elements. Three contingency plans were reviewed, one dedicated to the Mixing area, covering MMS and LABsystem; the second dedicated to the final PLT area, covering the systems present in Final Finishing and ContiSeal; the last dedicated to the APA, contemplating the systems present in this area. In the specific case of the contingency plan

Creating a contingency plan required additional work:

- It was necessary to collect information regarding the systems and analyse the MES and the impacts each system will have on production and other departments and systems, if applicable. Sections 5.2 and 5.3 explain this collection of information.

- Regarding the internal actions to be applied during the system, failure was essential to collect information with the LKU, resulting in a proposal for a contingency plan to present to the team.

- As in the review situation, the proposals were discussed with the teams, aligning the proposal with the shopfloor reality to make the contingency plan as executable as possible.

In the case of CGMS, it was crucial to adopt a different approach due to its complexity. Therefore, a meeting was held with the LKUs to determine the best strategy for carrying out the contingency plan. During this meeting, the LKUs suggested holding a first introductory meeting with all the directions to contextualise and define the best approach for future meetings. In collaboration with the directors, the meeting resulted in the constitution of the multidisciplinary team and the structure of a global contingency plan that would integrate PLT and CST. With this

decision, work began on defining the CGMS contingency plan. In addition, the multidisciplinary team divided the plan into operation areas: Preparation, Construction, and Curing, which allowed a better definition of the work plan. During the meeting, in order to validate the internal actions defined by the multidisciplinary team, was necessary consider the conduction of simulations. Section 6.2 will expose the results of these simulations as an insight into the contingency plan.

All multidisciplinary teams will review the contingency plans annually to ensure compliance with the IATF 16949 standard.

Chapter 6

Results

This chapter presents the results related to the Risk Assessment of the systems referred to in 5.5. In addition, the review of the CMIP Contingency Plan will also be discussed, as well as the creation of contingency plans derived from the MES Risk Assessment.

In the discussion of the results, the Model used to obtain them will be shown in each stage. Finally, after the contextualisation, the implementation of the Model as well as its results will be presented.

6.1 Systems risk identification

Section 5.5 explained the approach used for risk management. This section discloses the results of the risk assessment. Initially, presenting the criteria used for risk analysis and the Risk Register structure. Subsequently, the identified risks will then be presented, as well as a general assessment of the risks associated with the systems.

6.1.1 Probability, Impact and Class

As discussed in the section 5.6, it is necessary to identify the Probability and impact criteria to conduct the risk analysis. The Probability is defined as follows:

- **Low**: less than annually;
- **Medium**: between two to six times a year;
- **High**: more than six times a year.

The Impact is defined by:

- **Low**: at maximum, one machine per area is affected;
- **Medium**: affects half of the value-adding processes (for example, half of the mixing area stops production);

- **High**: affects at least one value-adding process (ex: mixing area stops).

After assigning the Probability and Impact criteria, each risk has a class associated. The purpose of this Class will be to warn which risks will be the target of a contingency plan or should result in corrective actions to reduce the risk. Therefore, for the attribution of this measure, a greater weight was considered in the Impact, as defined in Figure 6.1.

		Impact		
		Low 1	Medium 2	High 3
Probability	Low 1	Low	Medium	High
	Medium 2	Low	Medium	High
	High 3	Medium	High	High

Figure 6.1: Risk Matrix: Class

6.1.2 Definition of the Risk Register model and its application

As stated in section 5.5, the Risk Register model created can display all risks associated with the MES systems within the scope. The figure 6.2 represents the model applied in the CMIP, designed with DTI's management. Its application was carried out together with the LKUs of each system.

Risk ID	IDENTIFICATION		EVALUATION					TREATMENT				MONITORING		
	Risk	Description	Effect	Probability	Impact	Class	RBS Category	Mgmt. Decision needed?	Action	Owner	Due date	Risk status	Risk Class	Current status date

Figure 6.2: Template Risk Register

For each risk identified was designated the Impact and Probability criteria. Based on these criteria, a Class was assigned to each, defining the need to create IT contingency plans or corrective measures. The DTI established that all risks with a High class must be subject to contingency plans and that risks with a High probability must be subject to corrective measures.

As mentioned in section 5.6, the members of the IT direction decided, considering this project's scope, that the risks that should have priority in treatment will be the risks with the higher Class.

6.1.3 Risk Register Implementation

As mentioned in section 5.6, meeting with the LKUs was crucial to collect the results for each system, documented in the system Risk Register. In addition, creating a Risk Matrix for each system was essential to provide a visual analysis after identifying and analysing the risks.

6.1.3.1 CGMS

The analysis performed on the CGMS resulted in 14 risks, as seen in Figure 6.3.

Risk ID	IDENTIFICATION		Evaluation		
	Risk	Description	Probability	Impact	Class
R-01	Server unavailable	i. CGMS Server is unavailable (e.g., shutdown, or CPDA -> CPDB)	Low	High	High
		ii. VM is corrupted	Low	High	High
R-02	Database server unavailable	i. CGMS Database is unavailable	Low	High	High
		ii. CGMS Database is corrupted	Low	High	High
R-03	Daylight saving time	With the hour change some lot/carrier/articles can surfer changes	Low	Low	Low
R-04	WAN Network unavailable	Is impossible comunicate with the central systems (e.g., SAP PP)	Low	Medium	Medium
R-05	LAN Network unavailable	Is impossible to comunicate with any Manufacturing Suite System	Low	High	High
R-06	DIL unavailable	CGMS can't communicate with any system	Low	High	High
R-07	MMS unavailable	MMS can't communicate with CGMS	Low	Medium	Medium
R-08	EWM unavailable	CGMS can't communicate with EWM	Low	High	High
R-09	CGRS unavailable	CGMS can't communicate with CGRS	Low	Medium	Medium
R-10	WEB unavailable	Dashboard and all its functionalities are unavailable	Low	Medium	Medium
R-11	MTL unavailable	It isn't possible to send new receipes to machines.	Low	High	High
R-12	Schedule system update (server)	CGMS is updated, but a failure can occur	Low	High	High
R-13	SAP PP unavailable	CGMS can't communicate with SAP PP	Low	Medium	Medium
R-14	Restart production	Restart all services	Low	Low	Low

Figure 6.3: CGMS Risk Register

R01 - Server unavailable

This risk divides into two sub-risks: (i) - the CGMS server is unavailable, and (ii) VM is corrupted. While each sub-risk has the same impact on business continuity, the response provided by DTI will differ, hence the division. Nonetheless, both sub-risks have a low Probability and high Impact, given that, in the worst-case scenario, the production will stop in three value-adding processes. Considering the Probability and Impact, the Class attributed to these sub-risks was High. Given the high Impact, the proposed treatment measure to ensure business continuity was the creation of a CGMS contingency plan.

R02 - Database server unavailable

Like R01, R02 was divided into two sub-risks: (i) - CGMS Database is unavailable, and (ii) CGMS Database is corrupted. Similar to R01, both sub-risks have a low Probability and a high Impact. Like R01, this risk cannot be mitigated, being necessary to create a contingency plan.

R03 - Daylight saving time

With daylight saving time, the traceability of the production can be affected. Therefore, it was considered a risk to the system's proper functioning. Accordingly, it was assigned both a low Probability and Impact. The treatment measure established was the creation of a checklist for each daylight saving time to verify the system's proper functioning.

R04 - WAN Network unavailable

When the WAN fails, the connection between the CGMS and the central systems is unavailable. The Probability assigned was low, and considering this failure, the Impact was medium since, despite more than one area being affected, it is possible to continue to produce with some normality during the failure. Although the assigned Class is medium, the treatment action defined was a contingency plan for the WAN.

R05 - LAN Network unavailable

When the LAN fails, the connection between the CGMS and the other MSS systems fails. The Probability attributed to this risk is low, and its Impact is high. Similar to the previous risks, the treatment action suggested is creating a contingency plan for LAN.

R06 - DIL Network unavailable

A failure of the DIL implies two situations. Firstly, the connection between the CGMS and any system is interrupted, and secondly, between the client and the server. This risk presents a Low Probability and High Impact. The treatment action suggested was the creation of the DIL contingency plan.

R07 - MMS unavailable

This risk refers to the communication failure between the MMS and the CGMS. This Probability is Low, and its Impact is Medium because this failure only affects the preparation area. However, the Impact will only be visible after 2 hours since the material produced during the failure must rest for that period. The Class assigned to this risk was Medium, and as a treatment action, if the DP deems necessary, the MMS contingency plan should be activated.

R08 - EWM unavailable

Considering that the EWM manages stocks and coordinates the disposal of materials, this risk was assigned a low probability and a high impact. Corresponding to a high class and referring to creating an EWM contingency plan with treatment action.

R09 - CGRS unavailable

Like the two previous risks, this risk refers to the failure of communication between the CGMS and a manufacturing system. In this case, CGRS manages the recipes to be used by CGMS, so Probability was assigned the low category and impact the medium category. Given that in case of failure, all machines have all recipes used so far available. The recommended treatment measure would be to activate the CGRS contingency plan.

R10 - WEB unavailable

This risk refers to the unavailability of the CGMS dashboard. Low Probability and medium Impact were assigned since it is possible to continue producing. However, production control may be affected because the dashboard features are unavailable. In the worst-case scenario, the Production Control should communicate with the management of the affected areas.

R11 - MTL unavailable

This risk refers to the unavailability of the Message Transformation Layer, MTL. Low Probability and high Impact were assigned since it affects the possibility of sending recipes, orders to the machines, and also the validation process is affected. The treatment action suggested was activating the CGMS contingency plan.

R12 - Schedule system update

Even with a scheduled system update, unforeseen events may occur, affecting production. Therefore, it was considered a risk to the system's proper functioning. Accordingly, it was assigned a low Probability and High Impact. The treatment measure established was the creation of a checklist to verify the system's proper functioning, and if a failure is detected, DTI should perform a rollback.

R13 - SAP PP unavailable

Considering that the SAP PP manages the production flow within CGMS, this risk was assigned a low probability and a medium impact. Corresponding to a medium class and referring to creating an SAP PP contingency plan with treatment action.

R14 - Restart production

When the restart of production occurs, the production can be affected. This risk may occur in case of an incorrect restart of all services. Therefore, like the daylight saving time, it was considered a risk to the system's proper functioning. Accordingly, it was assigned both a low

Probability and Impact. The treatment measure established was the creation of a checklist to verify the system's proper functioning.

Risk Matrix

The risk matrix shows the risk distribution according to Impact and Probability, Figure 6.4, which resulted from the risk analysis.

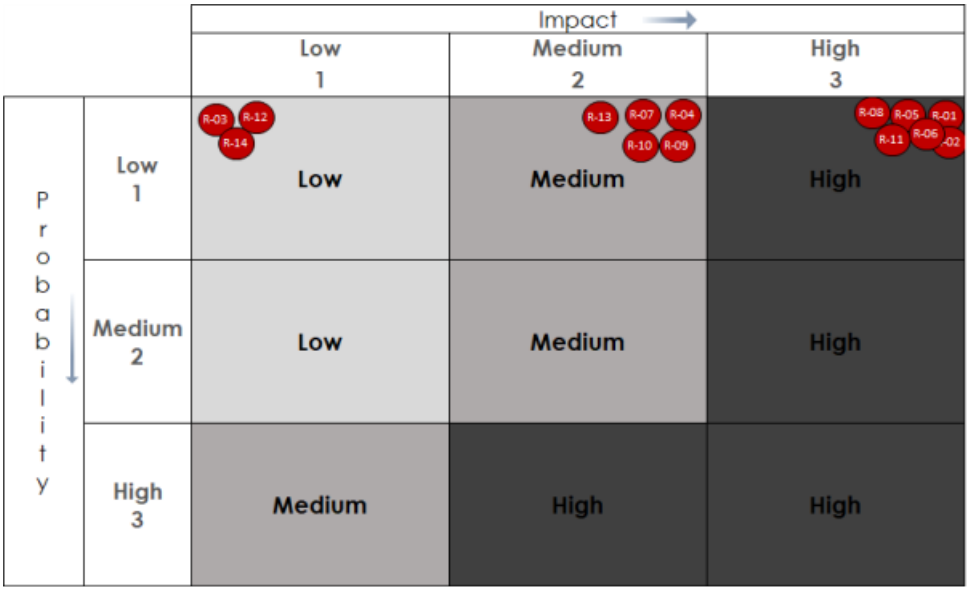

Figure 6.4: CGMS Risk Matrix

6.1.3.2 CGRS

The analysis performed on the CGRS resulted in 10 risks, as seen in Figure 6.5.

Risk ID	IDENTIFICATION		EVALUATION		
	Risk	Description	Probability	Impact	Class
R-01	Server unavailable	I. CGRS Server is unavailable (e.g., shutdown, or CPDA -> CPDB)	Low	High	High
		II. VM is corrupted	Low	High	High
R-02	Database server unavailable	I. CGRS Database is unavailable	Low	High	High
		II. CGRS Database is corrupted	Low	High	High
R-03	WAN Network unavailable	Is impossible comunicate with the central systems (e.g., SAP PP)	Low	High	High
R-04	LAN Network unavailable	Is impossible to comunicate with any Manufacturing Suite System	Low	High	High
R-05	CGMS unavailable	CGRS can't communicate with CGMS	Low	High	High
R-06	WPS unavailable	CGRS can't communicate with WPS	Medium	Medium	Medium
R-07	THERMO unavailable	CGRS can't communicate with THERMO	Low	High	High
R-08	Schedule system update	CGRS is updated, but a failure can occur	Low	Low	Low
R-09	Daylight saving time	With the hour change some recipes can surfer changes	Low	Low	Low
R-10	Restart operations	Restart all services	Low	Low	Low

Figure 6.5: CGRS Risk Register

R01 - Server unavailable

This risk divides itself into two sub-risks: (i) the CGRS server is down, and (ii) the VM is corrupted. While each sub-risk has the same impact on business continuity, DTI's response will vary, hence the division. Nonetheless, both sub-risks have a low Probability but a high Impact because, in the worst-case scenario, production will cease in three value-adding processes. Therefore, the Class assigned to these sub-risks was High. Given the severity of the impact, the proposed treatment measure to ensure business continuity was developing a CGRS contingency plan.

R02 - Database server unavailable

R02, like R01, has two sub-risks: (i) CGRS Database is unavailable, and (ii) CGRS Database is corrupted. Both sub-risks, like R01, have a low Probability but a high Impact. This risk, like R01, cannot be mitigated, necessitating the development of a contingency plan.

R03 - WAN Network unavailable

When the WAN fails, the connection between the CGRS and the central systems is unavailable. The Probability assigned was low, and considering this failure, the Impact was high. The assigned Class is high. The treatment action defined was a contingency plan for the WAN.

R04 - LAN Network unavailable

When the LAN fails, the connection between the CGRS and the other MSS systems fails. The Probability attributed to this risk is low, and its Impact is high. Similar to the previous risks, the treatment action suggested is creating a contingency plan for LAN.

R05 - CGMS unavailable

This risk refers to the failure of communication between the CGRS and a manufacturing system. In this case, CGMS uses the recipes managed by CGRS, so Probability was assigned the low category and impact the high category. The recommended treatment actions is activating the CGMS contingency plan.

R06 - WPS unavailable

This risk refers to the communication failure between the WPS and the CGRS. In this case, WPS sends the master material information to CGRS, so Probability was assigned the low category and impact the high category. The recommended treatment actions is activating the WPS contingency plan.

R07 - THERMO unavailable

This risk refers to the communication failure between the THERMO and the CGRS. In this case, THERMO sends the master material information to CGRS, so Probability was assigned the low category and impact the high category. Corresponding to a high class and referring to creating an THERMO contingency plan with treatment action.

R08 - Schedule system update

Even with a scheduled system update, unforeseen events may occur, affecting production. Therefore, it was considered a risk to the system's proper functioning. Accordingly, it was assigned a low Probability and High Impact. The treatment measure established was the creation of a checklist to verify the system's proper functioning, and if a failure is detected, DTI should perform a rollback.

R09 - Daylight saving time

With daylight saving time, the traceability of the production can be affected. Therefore, it was considered a risk to the system's proper functioning. Accordingly, it was assigned both a low Probability and Impact. The treatment measure established was the creation of a checklist for each daylight saving time to verify the system's proper functioning.

R10 - Restart production

Like CGMS, when the restart of production occurs, the production can be affected. This risk may occur in case of an incorrect restart of all services. Therefore, like the daylight saving time, it was considered a risk to the system's proper functioning. Accordingly, it was assigned both a low Probability and Impact. The treatment measure established was the creation of a checklist to verify the system's proper functioning

Risk Matrix

The risk matrix shows the risk distribution according to Impact and Probability, Figure 6.6, which resulted from the risk analysis.

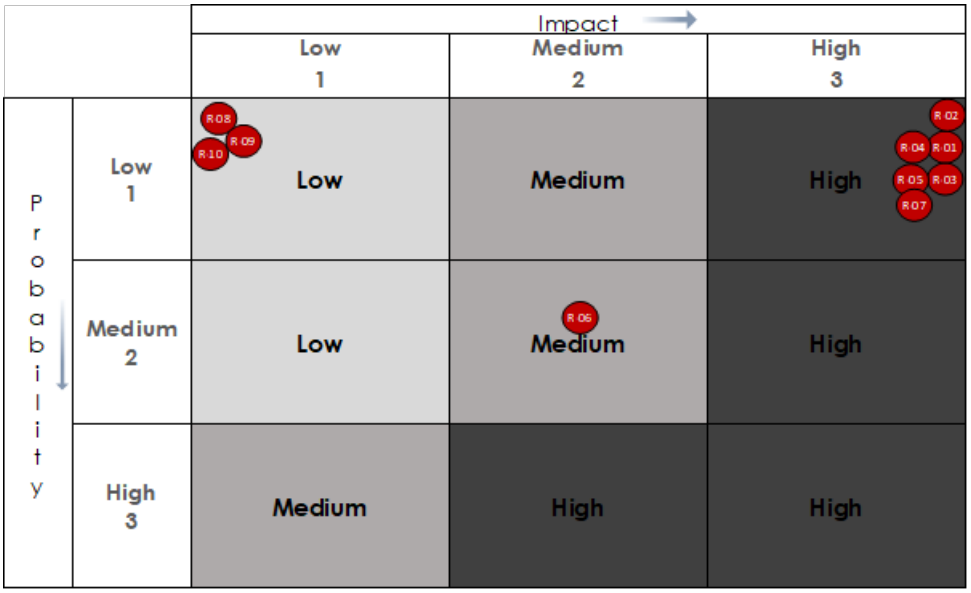

Figure 6.6: CGRS Risk Matrix

6.1.3.3 EWM

The analysis performed on the EWM resulted in 11 risks, as seen in Figure 6.7.

Risk ID	IDENTIFICATION		EVALUATION		
	Risk	Description	Probability	Impact	Class
R-01	SAP PP unavailable	No comunnication between SAP PP and EWM	Low	High	High
R-02	Server unavailable	i. EWM Server is unavailable (e.g., shutdown, or CPDA -> CPDB)	Low	High	High
		ii. VM is corrupted	Low	High	High
R-03	Database unavailable	i. EWM Database is unavailable	Low	High	High
		ii. EWM Database is corrupted	Low	High	High
R-04	WAN Network unavailable	Is impossible comunicate with the central systems (e.g., SAP PP)	Low	High	High
R-05	LAN Network unavailable	Is impossible to comunicate with any Manufacturing Suite System	Low	High	High
R-06	DIL unavailable	No communication between EWM and any system	Low	High	High
R-07	CGMS unavailable	No communication between EWM and CGMS	Low	High	High
R-08	Schedule system update	EWM is updated, but a failure can occur	Low	Low	Low
R-09	Daylight saving time	With the hour change some lot/carrier/articles can surfer changes	Low	Low	Low
R-10	Restart production	Restart all services	Low	Low	Low
R-11	HBS unavailable	No communication between EWM and HBS	Low	Medium	Medium

Figure 6.7: EWM Risk Register

R01 - SAP PP unavailable

Considering that the SAP PP manages the production flow, considering the stock update in EWM, this risk was assigned a low probability and a medium impact. Corresponding to a medium class and referring to creating an SAP PP contingency plan with treatment action.

R02 - Server unavailable

This risk divides into two sub-risks: (i) - the EWM server is unavailable, and (ii) VM is corrupted. While each sub-risk has the same impact on business continuity, the response provided by DTI will differ, hence the division. Nonetheless, both sub-risks have a low Probability and high Impact, given that, in the worst-case scenario, the production will stop in three value-adding processes. Considering the Probability and Impact, the Class attributed to these sub-risks was High. Given the high Impact, the proposed treatment measure to ensure business continuity was the creation of a EWM contingency plan.

R03 - Database server unavailable

Like R01, R02 was divided into two sub-risks: (i) - EWM Database is unavailable, and (ii) EWM Database is corrupted. Similar to R01, both sub-risks have a low Probability and a high Impact. Like R01, this risk cannot be mitigated, being necessary to create a contingency plan.

R04 - WAN Network unavailable

When the WAN fails, the connection between the EWM and the central systems is unavailable. The Probability assigned was low, and considering this failure, the Impact was high. The assigned Class is high. The treatment action defined was a contingency plan for the WAN.

R05 - LAN Network unavailable

When the LAN fails, the connection between the EWM and the other MSS systems fails. The Probability attributed to this risk is low, and its Impact is high. Similar to the previous risks, the treatment action suggested is creating a contingency plan for LAN.

R06 - DIL Network unavailable

A failure of the DIL implies two situations. Firstly, the connection between the EWM and any system is interrupted, and secondly, between the client and the server. This risk presents a Low Probability and High Impact. The treatment action suggested was the creation of the DIL contingency plan.

R07 - CGMS unavailable

Considering that the CGMS send the counts, carrier status and its location to EWM, this risk was assigned a low probability and a high impact. Corresponding to a high class and referring to activating the CGMS contingency plan as treatment action.

R08 - Schedule system update

Even with a scheduled system update, unforeseen events may occur, affecting production. Therefore, it was considered a risk to the system's proper functioning. Accordingly, it was assigned a low Probability and High Impact. The treatment measure established was the creation of a checklist to verify the system's proper functioning, and if a failure is detected, DTI should perform a rollback.

R09 - Daylight saving time

With daylight saving time, the traceability of the production can be affected. Therefore, it was considered a risk to the system's proper functioning. Accordingly, it was assigned both a low Probability and Impact. The treatment measure established was the creation of a checklist for each daylight saving time to verify the system's proper functioning.

R10 - Restart production

When the restart of production occurs, the production traceability can be affected. This risk may occur in case of an incorrect restart of all services. Therefore, like the daylight saving time, it was considered a risk to the system's proper functioning. Accordingly, it was assigned both a low Probability and Impact. The treatment measure established was the creation of a checklist to verify the system's proper functioning.

R11 - HBS unavailable

Considering that the High Base Storage, HBS, functions as a warehouse, in case of failure, the stock in HBS cannot be used by the production. Therefore, this risk was assigned a low probability and a high impact, corresponding to a high class. The treatment action suggested was the activation of EWM contingency plan.

Risk Matrix

The risk matrix shows the risk distribution according to Impact and Probability, Figure 6.8, which resulted from the risk analysis.

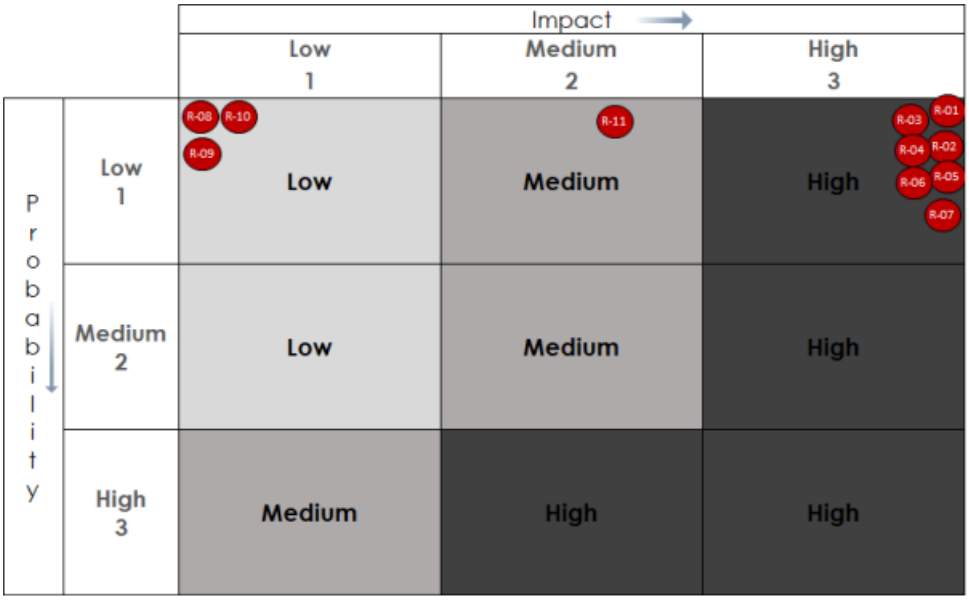

Figure 6.8: EWM Risk Matrix

6.1.3.4 FFDACS

The analysis performed on the FFDACS resulted in 7 risks, as seen in Figure 6.9.

Risk ID	IDENTIFICATION		EVALUATION		
	Risk	Description	Probability	Impact	Class
R-01	Server unavailable	i. FFDACS Server is unavailable (e.g., shutdown, or CPDA -> CPDB)	Low	High	High
		ii. VM is corrupted	Low	High	High
R-02	Database server unavailable	i. FFDACS Database is unavailable	Low	High	High
		ii. FFDACS Database is corrupted	Low	High	High
R-03	WAN Network unavailable	Is impossible comunicate with the central systems (e.g., SAP PP)	Low	High	High
R-04	LAN Network unavailable	Is impossible to comunicate with any Manufacturing Suite System	Low	High	High
R-05	MCAT unavailable	FFDACS can't communicate with MCAT	Low	High	High
R-06	Daylight saving time	With the hour chenge, alterations can occur	Low	Low	Low
R-07	Restart operations	Restart all services	Low	Low	Low

Figure 6.9: FFDACS Risk Register

R01 - Server unavailable

This risk divides into two sub-risks: (i) - the FFDACS server is unavailable, and (ii) VM is corrupted. While each sub-risk has the same impact on business continuity, the response provided by DTI will differ, hence the division. Nonetheless, both sub-risks have a low Probability and high Impact, given that, in the worst-case scenario, the production will stop in three value-adding processes. Considering the Probability and Impact, the Class attributed to these sub-risks was High. Given the high Impact, the proposed treatment measure to ensure business continuity was the creation of a FFDACS contingency plan.

R02 - Database server unavailable

Like R01, R02 was divided into two sub-risks: (i) - FFDACS Database is unavailable, and (ii) FFDACS Database is corrupted. Similar to R01, both sub-risks have a low Probability and a high Impact. Like R01, this risk cannot be mitigated, being necessary to create a contingency plan.

R03 - WAN Network unavailable

When the WAN fails, the connection between the EWM and the central systems is unavailable. The Probability assigned was low, and considering this failure, the Impact was high. The assigned Class is high. The treatment action defined was a contingency plan for the WAN.

R04 - LAN Network unavailable

When the LAN fails, the connection between the FFDACS and the other MSS systems fails. The Probability attributed to this risk is low, and its Impact is high. Similar to the previous risks, the treatment action suggested is creating a contingency plan for LAN.

R05 - MCAT unavailable

This risk refers to the communication failure between the MCAT and the FFDACS. This Probability is Low, and its Impact is High because without MCAT is impossible to perform tire inspection. The Class assigned to this risk was High, and as a treatment action, if the DP deems necessary, the MMS contingency plan should be activated.

R06 - Daylight saving time

With daylight saving time, the traceability of the production can be affected. Therefore, it was considered a risk to the system's proper functioning. Accordingly, it was assigned both a low Probability and Impact. The treatment measure established was the creation of a checklist for each daylight saving time to verify the system's proper functioning.

R07 - Restart production

When the restart of production occurs, the production can be affected. This risk may occur in case of an incorrect restart of all services. Therefore, like the daylight saving time, it was considered a risk to the system's proper functioning. Accordingly, it was assigned both a low Probability and Impact. The treatment measure established was the creation of a checklist to verify the system's proper functioning.

Risk Matrix

The risk matrix shows the risk distribution according to Impact and Probability, Figure 6.10, which resulted from the risk analysis.

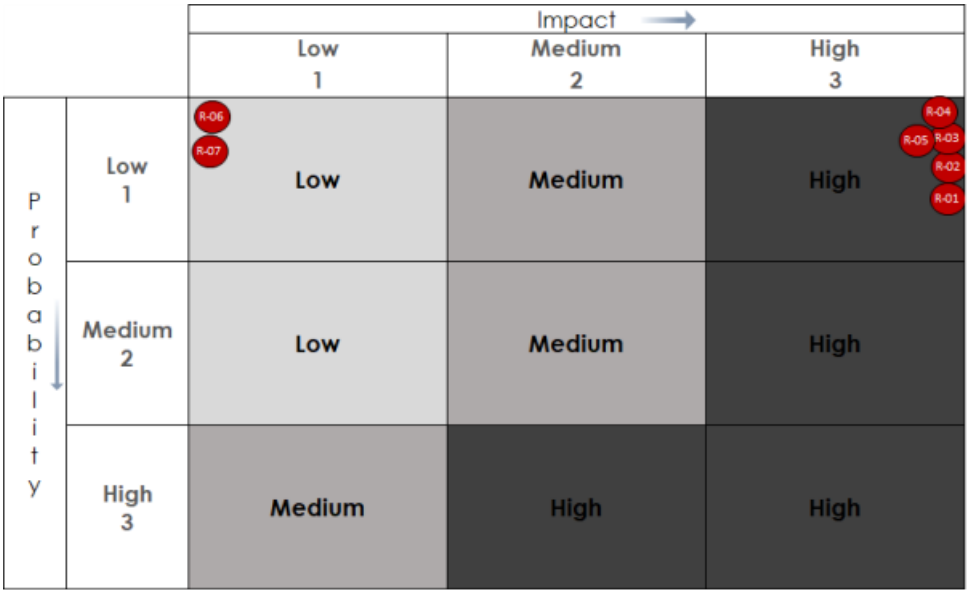

Figure 6.10: FFDACS Risk Matrix

6.1.3.5 MCAT

The analysis performed on the MCAT resulted in 11 risks, as seen in Figure 6.11.

Risk ID	IDENTIFICATION		Evaluation		
	Risk	Description	Probability	Impact	Class
R-01	Server unavailable	I. MCAT Server is unavailable (e.g., shutdown, or CPDA -> CPDB)	Low	High	High
		II. VM is corrupted	Low	High	High
R-02	Database server unavailable	I. MCAT Database is unavailable	Low	High	High
		II. MCAT Database is corrupted	Low	High	High
R-03	WAN Network unavailable	Is impossible comunicate with the central systems (e.g., SAP PP)	Low	High	High
R-04	LAN Network unavailable	Is impossible to comunicate with any Manufacturing Suite System	Low	High	High
R-05	DIL unavailable	MCAT can't communicate with CGMS	Low	High	High
R-06	CGMS unavailable	MCAT can't communicate with CGMS	Low	High	High
R-07	FFDACS unavailable	MCAT can't communicate with FFDACS	Low	High	High
R-08	FFTTS unavailable	MCAT can't communicate with FFTTS (scanners)	Low	High	High
R-09	Schedule system update	MCAT is updated, but a failure can occur	Medium	Low	Low
R-10	eLISA unavailable	MCAT can't communicate with eLISA	Low	Medium	Medium
R-11	Daylight saving time	With hour change some information ca surfer changes	Low	Low	Low

Figure 6.11: MCAT Risk Register

R01 - Server unavailable

This risk divides into two sub-risks: (i) - the MCAT server is unavailable, and (ii) VM is corrupted. While each sub-risk has the same impact on business continuity, the response provided by DTI will differ, hence the division. Nonetheless, both sub-risks have a low Probability and high Impact, given that, in the worst-case scenario, the production will stop in three value-adding processes. Considering the Probability and Impact, the Class attributed to these sub-risks was High. Given the high Impact, the proposed treatment measure to ensure business continuity was the creation of a MCAT contingency plan.

R02 - Database server unavailable

Like R01, R02 was divided into two sub-risks: (i) - MCAT Database is unavailable, and (ii) MCAT Database is corrupted. Similar to R01, both sub-risks have a low Probability and a high Impact. Like R01, this risk cannot be mitigated, being necessary to create a contingency plan.

R03 - WAN Network unavailable

When the WAN fails, the connection between the MCAT and the central systems is unavailable. The Probability assigned was low, and considering this failure, the Impact was medium since, despite more than one area being affected, it is possible to continue to produce with some normality during the failure. Although the assigned Class is medium, the treatment action defined was a contingency plan for the WAN.

R04 - LAN Network unavailable

When the LAN fails, the connection between the MCAT and the other MSS systems fails. The Probability attributed to this risk is low, and its Impact is high. Similar to the previous risks, the treatment action suggested is creating a contingency plan for LAN.

R05 - DIL Network unavailable

A failure of the DIL implies two situations. Firstly, the connection between the MCAT and any system is interrupted, and secondly, between the client and the server. This risk presents a Low Probability and High Impact. The treatment action suggested was the creation of the DIL contingency plan.

R06 - CGMS unavailable

This risk refers to the communication failure between the MCAT and the CGMS. This Probability is Low, and its Impact is High because this failure only affects the preparation area. However,

the Impact will only be visible after 2 hours since the material produced during the failure must rest for that period. The Class assigned to this risk was Medium, and as a treatment action, if the DP deems necessary, the MMS contingency plan should be activated.

R07 - FFDACS unavailable

Considering that the FFDACS manages recipes to measure the uniformity and balance, this risk was assigned a low probability and a high impact. Corresponding to a high class and referring to creating an FFDACS contingency plan with treatment action.

R08 - FFTTS unavailable

Like the two previous risks, this risk refers to the failure of communication between the MCAT and a manufacturing system. In this case, FFTTS manages the the transportation system, so Probability was assigned the low category and impact the medium category. As treatment action, DP operators remove the tires from the press treadmills, place them in pallets and move them to the processing areas in Final Finishing.

R09 - Schedule system update

Even with a scheduled system update, unforeseen events may occur, affecting production. Therefore, it was considered a risk to the system's proper functioning. Accordingly, it was assigned a medium Probability and low Impact. The treatment measure established was the creation of a checklist to verify the system's proper functioning, and if a failure is detected, DTI should perform a rollback. Differently from other systems, MCAT is currently in the version change phase, implying a higher probability. However, only happens during production stops.

R10 - eLISA unavailable

Considering that the eLISA manages the paperwork necessary for the merchandise to go from CMIP to the customer, this risk was assigned a low probability and a medium impact. Corresponding to a medium class and referring to creating an eLISA contingency plan with treatment action.

R11 - Daylight saving time

With daylight saving time, the traceability of the production can be affected. Therefore, it was considered a risk to the system's proper functioning. Accordingly, it was assigned both a low Probability and Impact. The treatment measure established was the creation of a checklist for each daylight saving time to verify the system's proper functioning.

Risk Matrix

The risk matrix shows the risk distribution according to Impact and Probability, Figure 6.12, which resulted from the risk analysis.

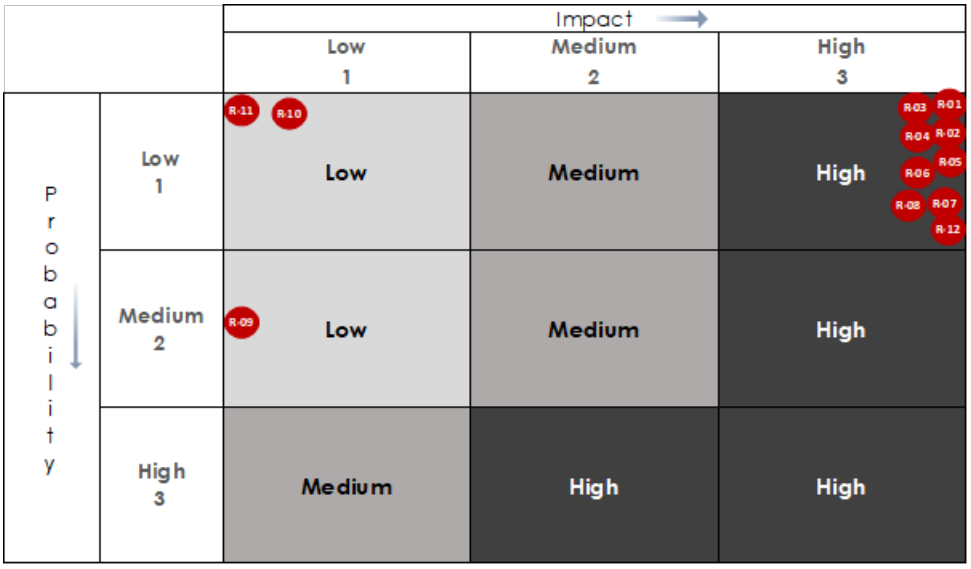

Figure 6.12: MCAT Risk Matrix

6.1.3.6 MMS

The analysis performed on the MMS resulted in 12 risks, as seen in Figure 6.13.

Risk ID	IDENTIFICATION		EVALUATION		
	Risk	Description	Probability	Impact	Class
R-01	Server unavailable	i. MMS Server is unavailable (e.g., shutdown, or CPDA -> CPDB)	Low	High	High
		ii. VM is corrupted	Low	High	High
R-02	Database server unavailable	i. MMS Database is unavailable	Low	High	High
		ii. MMS Database is corrupted	Low	High	High
R-03	WAN Network unavailable	Is impossible comunicate with the central systems (e.g., SAP PP)	Low	High	High
R-04	LAN Network unavailable	Is impossible to comunicate with any Manufacturing Suite System	Low	High	High
R-05	DIL unavailable	MMS can't communicate with any system	Low	Medium	Medium
R-06	CGMS unavailable	Communication between CGMS and MMS unavailable	Low	Medium	Medium
R-07	LABsystem unavailable	Communication between LabSystem and MMS unavailable	Low	High	High
R-08	CBS3 unavailable	Communication between CBS3 and MMS unavailable	Low	Medium	Medium
R-09	SAP PP unavailable	Communication between SAP PP and MMS unavailable	Low	High	High
R-10	Schedule system update	MMS is updated, but a failure can occur	Low	Low	Low
R-11	Daylight saving time	With the hour change some lot/carrier/articles can surfer changes	Low	Low	Low
R-12	Restart production	Restart all services	Low	Low	Low

Figure 6.13: MMS Risk Register

R01 - Server unavailable

This risk divides into two sub-risks: (i) - the MMS server is unavailable, and (ii) VM is corrupted. While each sub-risk has the same impact on business continuity, the response provided by DTI will differ, hence the division. Nonetheless, both sub-risks have a low Probability and high Impact, given that, in the worst-case scenario, the production will stop in three value-adding processes. Considering the Probability and Impact, the Class attributed to these sub-risks was High. Given the high Impact, the proposed treatment measure to ensure business continuity was the creation of a MMS contingency plan.

R02 - Database server unavailable

Like R01, R02 was divided into two sub-risks: (i) - MMS Database is unavailable, and (ii) MMS Database is corrupted. Similar to R01, both sub-risks have a low Probability and a high Impact. Like R01, this risk cannot be mitigated, being necessary to create a contingency plan.

R03 - WAN Network unavailable

When the WAN fails, the connection between the MMS and the central systems is unavailable. The Probability assigned was low, and considering this failure, the Impact was medium since, despite more than one area being affected, it is possible to continue to produce with some normality during the failure. Although the assigned Class is medium, the treatment action defined was a contingency plan for the WAN.

R04 - LAN Network unavailable

When the LAN fails, the connection between the MMS and the other MSS systems fails. The Probability attributed to this risk is low, and its Impact is high. Similar to the previous risks, the treatment action suggested is creating a contingency plan for LAN.

R05 - DIL Network unavailable

A failure of the DIL implies two situations. Firstly, the connection between the MMS and any system is interrupted, and secondly, between the client and the server. This risk presents a Low Probability and High Impact. The treatment action suggested was the creation of the DIL contingency plan.

R06 - CGMS unavailable

This risk refers to the communication failure between the MMS and the CGMS. This Probability is Low, and its Impact is Medium because the information produced during the failure can be

resend to CGMS. The Class assigned to this risk was Medium, and as a treatment action, if the DP deems necessary, the MMS contingency plan should be activated.

R07 - LABsystem unavailable

This risk refers to the communication failure between the MMS and the LABsystem. This Probability is Low, and its Impact is High because this failure implies the lack of quality validation of the produced material. The Class assigned to this risk was High, and as a treatment action, if the DP deems necessary, the LABsystem contingency plan should be activated.

R08 - CBS3 unavailable

This risk refers to the communication failure between the MMS and the CBS3. This Probability is Low, and its Impact is Medium because the information present in CBS3 can be upload manually in MMS. The Class assigned to this risk was Medium, and as a treatment action, if the DP deems necessary, the CBS3 contingency plan should be activated.

R09 - SAP PP unavailable

Considering that the SAP PP manages the production flow within MMS, this risk was assigned a low probability and a high impact. Corresponding to a high class and referring to creating an SAP PP contingency plan with treatment action.

R10 - Schedule system update

Even with a scheduled system update, unforeseen events may occur, affecting production. Therefore, it was considered a risk to the system's proper functioning. Accordingly, it was assigned a low Probability and High Impact. The treatment measure established was the creation of a checklist to verify the system's proper functioning, and if a failure is detected, DTI should perform a rollback.

R11 - Daylight saving time

With daylight saving time, the traceability of the production can be affected. Therefore, it was considered a risk to the system's proper functioning. Accordingly, it was assigned both a low Probability and Impact. The treatment measure established was the creation of a checklist for each daylight saving time to verify the system's proper functioning.

R12 - Restart production

When the restart of production occurs, the production can be affected. This risk may occur in case of an incorrect restart of all services. Therefore, like the daylight saving time, it was considered a risk to the system's proper functioning. Accordingly, it was assigned both a low Probability and Impact. The treatment measure established was the creation of a checklist to verify the system's proper functioning.

Risk Matrix

The risk matrix shows the risk distribution according to Impact and Probability, Figure 6.14, which resulted from the risk analysis.

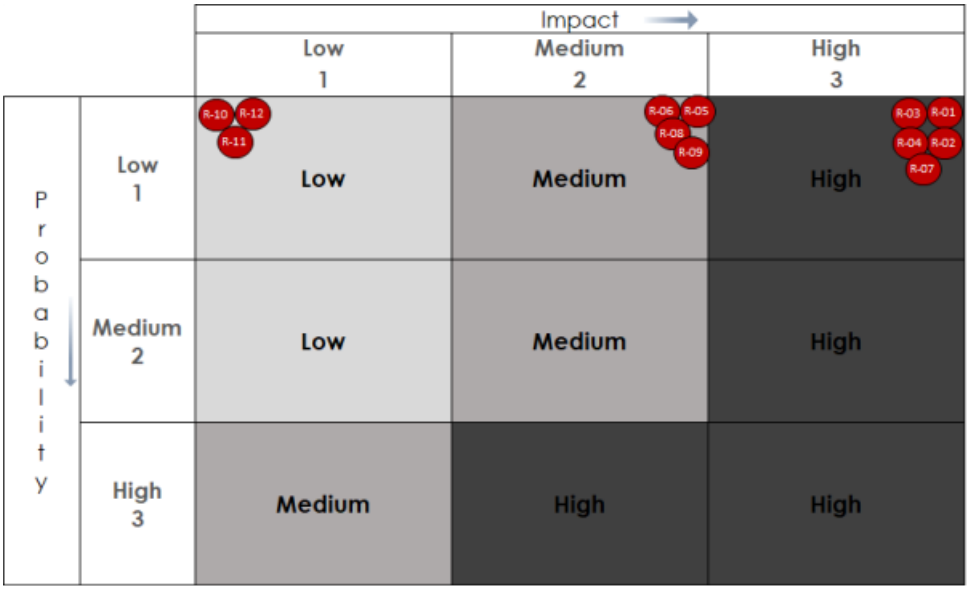

Figure 6.14: MMS Risk Matrix

6.1.4 Results discussion

The previous topics presented the risks per system. A treatment action was determined for each of these risks if it was verified. As the action in several instances, given the impossibility of mitigating the risks presented before, was suggested to create a contingency plan.

Therefore, considering the scope, during this project, contingency plans were developed for the following systems:

- CGMS;
- CGRS;
- EWM;

- MCAT, FFDACS and eLISA;
- MMS and LABsystem.

However, it was exposed to DTI what other contingency plans would be necessary to ensure the continuity of the business should any of these risks arise, being those:

- LAN Contingency plan;
- WAN Contingency plan;
- DIL Contingency plan;
- CBS3 Contingency plan;
- SAP PP Contingency plan;
- WPS Contingency plan;
- THERMO Contingency plan.

6.2 CMIP Contingency Plan

As mentioned in section 5.5, during the review phase of the general contingency plan, a review of the general risks present in the CMIP contingency plan was carried out. Therefore, the following sections address the structure of the risk register and the results obtained.

6.2.1 Severity, Occurrence, and Detention Factors

In order to determine the failure modes, it is necessary to identify the occurrence, severity, and detention. Central DQ defines each factor, while CMIP DQ adapts them to their reality. Therefore, these factors are transversal to all CMIP contingency plan documents. Each factor divides itself into four levels.

CMIP DQ attribute to severity the following classification levels:

- **1**: it does not affect the usual pace of production.
- **3**: it affects the usual pace of production.
- **7**: it does not directly affect the client.
- **10**: it directly affects the client.

The four levels of the occurrence factor are:

- **1**: it never occurs.
- **3**: occurs one time every ten years.
- **7**: occurs one time every five years.
- **10**: occurs frequently.

The classification for the detentions factor is as follows:

- **1**: the breakdown is immediately detected.
- **3**: it takes up to twelve hours to detect the breakdown.
- **7**: it takes up to twenty-four hours to detect the breakdown.
- **10**: it takes up to forty-eight hours to detect the breakdown.

6.2.2 FMEA model and its application

The CMIP contingency plan document was created based on the FMEA methodology model, represented in figure 6.15. Three parts constitute this document: PLT, CST, and general points (supporting processes).

Contingency Plan Item	Failure mode	Severity (S)	Ocorrence (O)	Contingency action	Detection (D)	RPN (S)*(O)*(D)

Figure 6.15: FMEA: structure

As explained in section 5.5, the DTI management performed the revision of the CMIP contingency plan, applying the FMEA methodology and identifying the failure modes in each of the three DTI departments. Then, the failure modes were divided according to their respective effects, causes, and existing controls, with indices S, O, and D assigned to each effect caused by its corresponding failure mode. Furthermore, the DTI defined the contingency action for each failure mode, considering the calculated Risk Priority Number, RPN, index.

After identifying the potential failures and calculating the RPN, the simulation priority follows a decreasing order, prioritising failures with the highest RPN index. As a rule, DQ schedules three simulations with the highest index for each plant, PLT and CST, and for general points.

6.2.3 FMEA Implementation

For CMIP's general contingency plan, as mentioned in the previous section, DTI contributes to the three parts of this plan. The following topics present the results obtained.

6.2.3.1 General Points

CMIP DQ divided the general points into eight parts, only one of which is in the scope of the DTI. Figure 6.16 shows the failure modes related to the DTI.

Contingency Plan Item	Failure mode consequence	Severity (S)	Ocorrence (O)	Detection (D)	RPN (S)*(O)*(D)
4. DTI					
Network **(GP4.1)**	Implossibility of access to any system or application	10	1	1	10
Comunication Network **(GP4.2)**	Impossibility of making voice communication via landlines.	10	3	1	30
Communication Network **(GP4.3)**	Impossibility of making voice communication via mobile phones.	10	3	1	30
Information systems **(GP4.4)**	Access to user data and application, inaccessible production support systems.	10	1	1	10
Data unavailability and corruption **(GP4.5)**	Shutdown of production support systems (manufacturing)	10	1	1	10
Data unavailability and corruption **(GP4.6)**	Inability to perform taks by users.	7	1	1	7
Cyber security **(GP4.7)**	Cyberattack	10	1	1	10

Figure 6.16: CMIP Contingency Plan: General Points

Network - GP4.1

This failure mode was evaluated with a severity level of 10, as the impossibility of accessing any system or application will result in reprogramming production planning for both plants. This failure can present itself as, in the best case, the failure of a datacenter (less impact on production) or failure of a fiber cable, switch, or another part of the network (impact on production will depend on the affected area). Considering all the alternatives covered by this failure mode, an occurrence level of 1 was assigned since it may occur with a low probability. The user can promptly detect the failure. Therefore, the level of detention equal to 1 was assigned. Currently, as a contingency measure, the following actions are verified:

- Connection to the central IT infrastructure ensured by different fiber paths;
- Computer racks are redundantly connected to the two datacenters.

Communication network - GP4.2

This failure mode represents the reduction of communication lines between the customers and CMIP. Therefore, the classification of the severity factor is a 10 since the customer is directly affected by this failure mode. Despite having a high severity level, this situation has a remote

probability of happening and can be detected immediately by users, so both occurrence and detention factors have a classification of 1. As a contingency measure, the users should resort to the mobile network.

Communication network - GP4.3

Similar to the GP4.2 failure mode, it was assigned a severity level of 10, level 1 for occurrence, and level 1 for detection. This failure mode is the inverse of GP4.2, so if the mobile communication fails, the users should resort to fixed communication.

Information systems - GP4.4

Accessing user data, applications, and production support systems in this failure mode is impossible. Therefore, a severity level of 10 was assigned, as it only affects the normal rhythm of production, the level of occurrence assigned was 1, as was the level of detention. As a contingency measure, DTI must activate the Disaster Recovery plan.

Data unavailability and corruption - GP4.5

This failure mode contemplates the complete stop of the production support systems, and this failure will have an immediate impact on the customer, so its severity level will be 10, as in GP4.4, its occurrence and detention levels will be 1. The contingency measure defined for this failure mode will be the activation of the disaster recovery plan.

Data unavailability and corruption - GP4.6

In this failure mode, users cannot perform tasks. However, as in failure mode GP4.4, there is no direct impact on customers, with the assigned severity factor being 7 and the Occurrence and detention factors 1. The contingency measure associated with this failure mode was the same designated for modes GP4.4 and GP4.5.

Cybersecurity - GP4.7

This failure mode has the effect of a cyberattack. As the production may stop immediately, the classification assigned to the severity factor was a 10. In terms of occurrence, so far, no cyberattack has occur, so level 1 was assigned. At the detection level, considering the categories defined by the DQ, level 1 was assigned. As a contingency measure, it was determined, by DTI, that the shopfloor network is independent of the office network, and in the event of an attack, users leave from having access to the data until the situation is normalised. DTI is establishing new control measures for cybersecurity, one of its primary goals this year.

Results discussion

In the general points section, DTI identified seven failure modes, six of which had a severity level of 10. That is, they have a high severity level. This situation arises because DTI is a support process, and its actions will immediately impact the production process. Regarding the occurrence factor, all failure modes identified have a low occurrence factor, with the highest assigned to level 3. Concerning the detection level, all failure modes identified have a classification of 1.

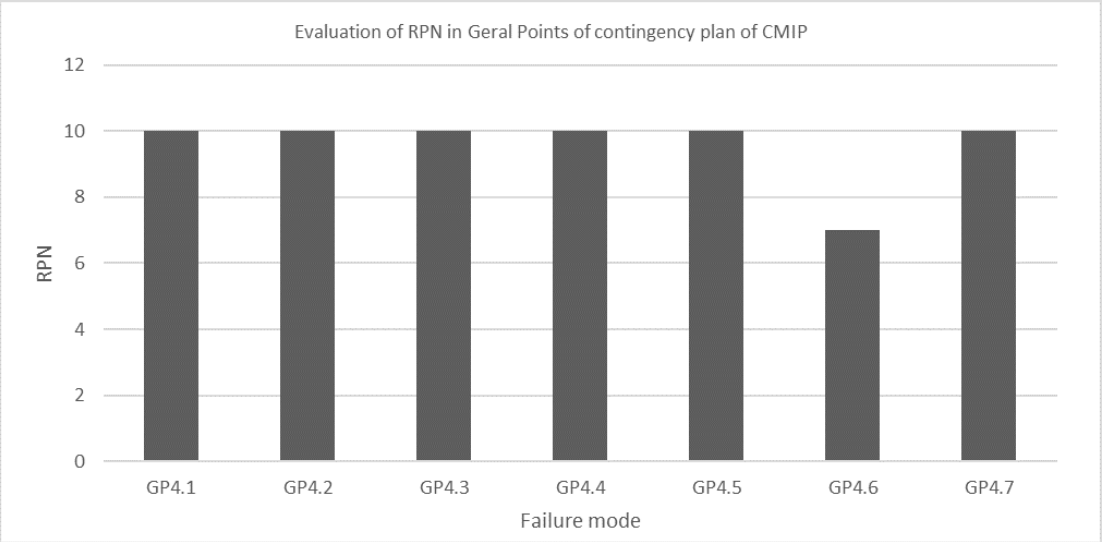

Figure 6.17: RPN graphical representation: General Points

In the figure 6.17, it is possible to observe the RPN of the identified failure modes, which DQ will then use to build its simulation plan.

6.2.3.2 PLT

CMIP DQ divided the PLT section into six parts, one for each value-adding process of the PLT production; figure 6.18 shows the failure modes related to the DTI.

Figure 6.18 shows 14 failure modes, which the following topics will analyse. The first step of this analysis was to group the failure mode by the MES system. This decision derives from the fact that the classification of FMEA factors is transversal, independent of the value-adding process.

MMS and LABsystem unavailable - PLT1.1

This failure mode contemplates the complete stop of the MMS and LABsystem. This failure will immediately impact the production but not the client OE, so its severity level will be 7. Due to the record of past failures, its occurrence and detention factors will be 3 and 1, respectively. The

Contingency Plan Item	Failure mode consequence	Severity (S)	Ocorrence (O)	Detection (D)	RPN (S)*(O)*(D)
1. Mixing					
MMS and Labsystem unavailable **(PLT1.1)**	Unable to load new orders into mixers or small chemical stations (orders in progress continue to work). Unable to print labels with barcodes.	7	3	1	21
2. Preparation					
CGRS Unavailable **(PLT2.1)**	Unable to update recipes.	3	3	1	9
EWM Unavailable **(PLT2.2)**	Inability to extend the expiration date of materials. Unable to update stocks.	7	3	1	21
CGMS Unavailable **(PLT2.3)**	Unable to receive new orders, and other production functions.	10	3	1	30
3. Tire Building					
CGRS Unavailable **(PLT3.1)**	Unable to update recipes.	3	3	1	9
EWM Unavailable **(PLT3.2)**	Inability to extend the expiration date of materials. Unable to update stocks.	7	3	1	21
CGMS Unavailable **(PLT3.3)**	Unable to receive new orders, and other production functions.	10	3	1	30
4. Curing					
CGRS Unavailable **(PLT4.1)**	Unable to update recipes.	3	3	1	9
EWM Unavailable **(PLT4.2)**	Inability to extend the expiration date of materials. Unable to update stocks.	7	3	1	21
CGMS Unavailable **(PLT4.3)**	Unable to receive new orders, and other production functions.	10	3	1	30
5. Final Finishing					
CGRS Unavailable **(PLT5.1)**	Unable to update recipes.	3	3	1	9
MCAT Unavailable **(PLT5.1)**	Impossibillity to inspect tyres and measure balance and uniformity	10	3	1	30
6 ContiSeal					
CGRS Unavailable **(PLT6.1)**	Unable to update recipes.	3	3	1	9
MCAT Unavailable **(PLT6.1)**	Impossibillity to inspect tires and measure balance and uniformity	10	3	1	30

Figure 6.18: CMIP Contingency Plan: PLT

contingency measure defined for this failure mode will be activating the MMS and LABsystem contingency plan.

CGRS unavailable - PLT2.1, PLT3.1, PLT4.1, PLT5.1 and PLT6.1

In this failure mode, CGRS is unavailable, implying that the users cannot update or create new recipes in five value-adding processes. However, the production can adapt to the failure in the meantime, so its severity factor will be 3. Due to past evidence, its occurrence and detection

are 3 and 1, respectively. The failure mode has the activation of the CGRS contingency plan as contingency action.

EWM unavailable - PLT2.2, PLT3.2 and PLT4.2

This failure mode affects three value-adding processes and regards stock and nonconformities management. Like PLT 1.1, this failure will immediately impact the production, not the client OE. Accordingly, its severity level will be 7. After evaluating the information available, the classification given to the occurrence and detection was 3 and 1. The contingency action recommended is the activation of the EWM contingency plan.

CGMS unavailable - PLT2.3, PLT3.3 and PLT4.3

Like the previous failure mode, this affects three value-adding processes, concerning every production function in these processes, excluding the update and creation of recipes. Therefore, the severity factors attributed to this mode was a 10, given the direct impact on the client. Like the previous modes, considering the information available, the classification given to the occurrence and detection was 3 and 1. The contingency measure advised is the activation of the CGMS contingency plan.

MCAT unavailable - PLT5.2 and PLT6.2

The main consequences of this failure mode are the impossibility of inspecting tires, measuring their balance and uniformity, and palletizing them in both Final Finishing and ContiSeal processes. In addition, this failure mode directly impacts the client, given that the classification provided was a 10. At the same time, its occurrence is a 3 and its detection a 1. Therefore, the contingency measure applied is the activation of the MCAT contingency plan.

Results discussion

In the PLT section, DTI identified fourteen failure modes, five of which had a severity level of 10. That is, they have a high severity level. This situation arises because DTI is a support process, and its actions will immediately impact the production process. Regarding the occurrence factor, all failure modes identified have a low occurrence factor, with the highest assigned to level 3. Concerning the detection level, all failure modes identified have a classification of 1.

In the image 6.19, it is possible to observe the RPN of the identified failure modes, which DQ uses to build its simulation plan. For 2022, the DQ planned the simulation of the following failure modes: PLT2.3 and PLT3.3. The figure 6.20 shows the results from this simulations.

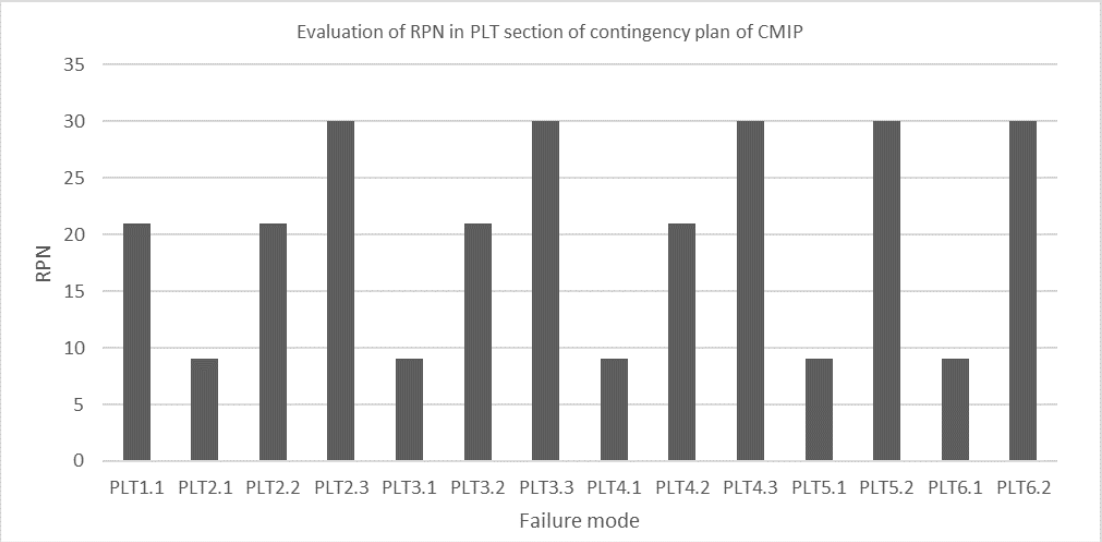

Figure 6.19: RPN graphical representation: PLT

Contingency Plan Item	Failure mode consequence	Severity (S)	Ocorrence (O)	Detection (D)	RPN (S)*(O)*(D)	Simulation - Expected Date	Simulation Date	Contingency Plan Efficiency
CGMS Unavailable - Preparation	Unable to receive new orders, and other production functions.	10	3	1	30	dez/22	mai/22	100% Evidências
CGMS Unavailable - Tire Building	Unable to receive new orders, and other production functions.	10	3	1	30	dez 22/	mai/22	100% Evidências

Figure 6.20: Simulations results: PLT

From each simulation resulted a document, which contains the following information:

- Date and hour;
- Machine and production unit;
- Production affected;
- Operation and internal actions;
- Effects;
- Recuperation action;
- Observations.

6.2.3.3 CST

CMIP DQ divided the CST section into four parts, one for each value-adding process of the CST production; figure 6.21 shows the failure modes related to the DTI.

Contingency Plan Item	Failure mode consequence	Severity (S)	Ocorrence (O)	Detection (D)	RPN (S)*(O)*(D)
1. Preparation					
CGRS Unavailable **(CST1.1)**	Unable to update recipes.	3	3	1	9
EWM Unavailable **(CST1.2)**	Inability to extend the expiration date of materials. Unable to update stocks.	7	3	1	21
CGMS Unavailable **(CST1.3)**	Unable to receive new orders, and other production functions.	10	3	1	30
2. Tire Building					
CGRS Unavailable **(CST2.1)**	Unable to update recipes.	3	3	1	9
EWM Unavailable **(CST2.2)**	Inability to extend the expiration date of materials. Unable to update stocks.	7	3	1	21
CGMS Unavailable **(CST2.3)**	Unable to receive new orders, and other production functions.	10	3	1	30
3. Curing					
CGRS Unavailable **(CST3.1)**	Unable to update recipes.	3	3	1	9
EWM Unavailable **(CST3.2)**	Inability to extend the expiration date of materials. Unable to update stocks.	7	3	1	21
CGMS Unavailable **(CST3.3)**	Unable to receive new orders, and other production functions.	10	3	1	30
4. Final Finishing					
CGRS Unavailable **(CST4.1)**	Unable to update recipes.	3	3	1	9
MCAT Unavailable **(CST4.1)**	Impossibillity to inspect tires and measure balance and uniformity	7	3	1	21

Figure 6.21: CMIP Contingency Plan: CST

As in PLT, when a system fails, it will affect its entirety. Therefore, to simplify the analysis of the failure modes present in CST under the responsibility of the DTI, they were grouped into four distinct modes (by MES system), which will be analysed below.

CGRS unavailable - CST1.1, CST2.1, CST3.1 and CST4.1

CGRS is unavailable in this failure mode, implying that users cannot update or create new recipes in the four value-adding processes. However, in the meantime, the production can adapt to the failure, so its severity factor will be 3. Its occurrence and detection are 3 and 1, respectively, based on previous evidence. Activating the CGRS contingency plan is the contingency action in the failure mode.

EWM unavailable - CST1.2, CST2.2 and CST3.2

This failure mode impacts three value-added processes, including stock and nonconformities management. This failure will immediately impact production rather than the client OE. As a result, its severity level will be 7. After reviewing the available data, the classifications for occurrence and detection were 3 and 1. The recommended contingency action is to activate the EWM contingency plan.

CGMS unavailable - CST1.3, CST2.3 and CST3.3

This failure mode, like the previous one, affects three value-adding processes and every production function, except for recipe update and creation. As a result of the direct impact on the client, the severity factors assigned to this mode were a ten. Considering the available information, the classification given to the occurrence and detection was 3 and 1. Therefore, the suggested contingency measure is to activate the CGMS contingency plan.

MCAT unavailable - CST4.2

The primary consequences of this failure mode are the inability to inspect tires and measure their balance, uniformity, and other parameters during the Final Finishing process. Furthermore, because the classification provided was a 10, this failure mode directly impacts the client. At the same time, its occurrence factor is a 3, while its detection is a 1. As a result, the contingency measure used is the activation of the MCAT contingency plan.

Results discussion

In the CST section, DTI identified eleven failure modes, three of which had a severity level of 10. This situation arises because of the impact of CGMS system in the production, and its actions will immediately impact the production process. Regarding the occurrence factor, all failure modes identified have a low occurrence factor, with the highest assigned to level 3. Concerning the detection level, all failure modes identified have a classification of 1.

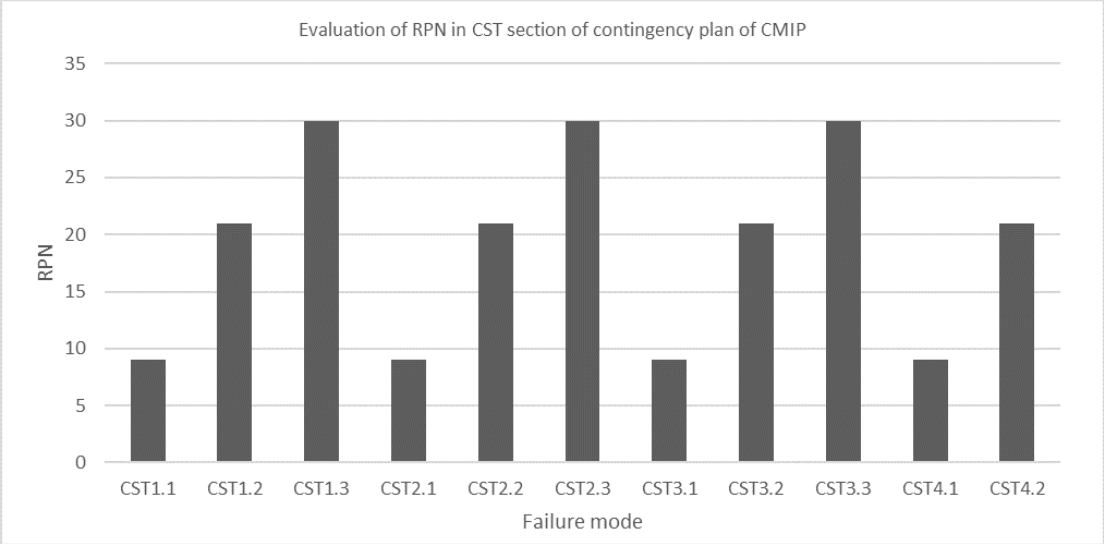

Figure 6.22: RPN graphical representation: CST

In the image 6.22, it is possible to observe the RPN of the identified failure modes, which DQ will then use to build its simulation plan.

6.3 Contingency Plans

Previously, the activation of various contingency plans was mentioned, either in response to various risks associated with the systems (section 6.1) or as a contingency measure (referred to in section 6.2).

As discussed in section 5.5, the systems analysed were: CGMS, CGRS, EWM, FFDACS, MCAT and MMS. These were the contingency plans developed in this project.

Considering the complexity of the systems and their interactions, as mentioned in 5.8, for some systems, a contingency plan was carried out for each manufacturing or business unit, while for others, only a global contingency plan.

Therefore, the contingency plans created were:

6.3.1 Multidisciplinary Teams

As previously mentioned, to carry out the contingency plans, it was necessary to create several multidisciplinary teams. Figure 6.23 represents the composition of these teams by contingency plan carried out.

	Contingency Plan	Multidisciplinar Team
Revision	PLT – Final Finishing and Contiseal	- **LKUs**: MCAT; FFDACS and Grading - **Production**: DP5 and ContiSeal Managers - **Other directions:** DQ; DOL; DEI; DEM6; DTI
	PLT - Mixing	- **LKUs**: MMS and LABsystem - **Production**: DP1 and Lab Managers - **Other directions**: DQ; DP-CP; DEI; DEP; DTI; DIP; DEM
	PLT and CST - APA	- **LKU**: MCAT - **Production**: APA Manager - **Other directions**: DQ; DOL; DEI; DEM; DTI
Development	CST - Final Finishing	- **LKUs**: MCAT; FFDACS and Grading - **Production**: CU&FF Manager - **Other directions**: DQ; DOL; DEI; DEM8; DTI
	PLT and CST - EWM	- **LKUs**: EWM and CGMS - **Production**: PLT Deputy and CST Deputy - **Other directions**: DQ; DOL; DEI; DEM6; DTI
	PLT - CGRS	- **LKU**: CGRS - **Production**: PLT Director - **Other directions**: DQ, DEP, DEM, DIP, DTI
	CST - CGRS	- **LKU**: CGRS - **Production**: CST Director - **Other directions**: DQ, DEP, DEM, DIP, DTI
	PLT and CST - CGMS	- **LKUs**: CGMS - **Production**: PLT and CST Deputies - **Other directions**: DQ, DEP, DEM, DEI

Figure 6.23: Multidisciplinary teams by contingency plan

6.3.2 Contingency Plan Matrix

As mentioned in section 5.8, for each contingency plan, there is a matrix that represents it. For the definition of the Contingency Plan Matrix, the structure used in contingency plans was the one previously defined by the organisation. Figure 6.24 demonstrates an example of the structure.

Therefore, the Contingency Plan Matrix should contain the following information:

- Identify the area of application of the plan;
- Identify the person responsible for activating and following the contingency plan and that of his replacement;
- Identify the author and the participants in the working group responsible for preparing the individual plan;
- Identification of affected IT systems;
- Process information to quantify the products, items and aspects affected by the contingency;

Contingency Plan - EWM			
Responsable for ativativate the contingency plan and follow-up: Multidisciplinary Team Autor:			
Information: - System unavailable: EWM - Daily Production [tires]	**Nível A**	**Nível B**	**Nível C**
Time [hour] (after Emergency Plan activation)			
Situation Nr. of affected tires			
Communication Chain	0 **IT (HD or *Call in*) [1+3]** 1 **IT Manager [0+2]** 2 - Production Manager 2 - Production Control 2 - Local Key User [s] 3 - Production Department Supervisors 3 - Production Department Managers (or Superintendent on 2st and 3rd shift and weekends)	**IT (HD or *Call in*) [1+3]** **IT Manager [0+2]** - Production Manager - Production Control - Local Key User [s] - Production Department Supervisors - Production Department Managers (or Superintendent on 2st and 3rd shift and weekends)	**IT (HD or *Call in*) [1+3]** **IT Manager [0+2]** - Production Manager - Production Control - Local Key User [s] - Production Department Supervisors - Production Department Managers (or Superintendent on 2st and 3rd shift and weekends)
Next level:	IT Manager	IT Manager	-
Periodic notification	IT Manager (every hour)	IT Manager (every hour)	-
Internal actions	- Scheduling and/or Shift Supervisor evaluate impact and notify LKU; - Scheduling prints transportation list (SPL) to help material handlers.	- LKUs open central ticket.	- All Upper Management has to decide on where to go next by.
Necessary resources	- Manterial handlers and operators; - Available hardware; - CGMS and EWM LKUs.	- Manterial handlers and operators; - Available hardware; - CGMS and EWM LKUs; - CKU, RKU and CCM.	
Internal Impact	- Update of SAP PP unavailable; - Production planning affected.	- Create new request in EWM unavailable; - Stock variations.	
Impact in other processes	- Produced goods can't be validate in next production step.	- Production can stop due to validation rules; - Carrier localizations unavailable.	
External impact	-	-	
External actions	-	-	
Recovery Actions	- Update the material locations in EWM [DP] - Check communication status between EWM and other systems [SYSMGT] - If possible, use (EWM) SCWM/ERP_STOCKCHECK transaction to update stock in SAP PP [Scheduling] - Check HBS stock with EWM, and update stocks on EWM side. [EWM LKU] - If update via DIL unavailable, use application LOInventory to make inventory of the materials and manually upload it. [DP e EWM LKU]		

Figure 6.24: Contingency Plan Matrix Example. Due to the company's confidentiality policy, information hidden in red cannot be made available.

- Severity levels: the contingency plan should consider different levels of severity, considering the time elapsed after its activation;
- Information on each level of severity: associated with the levels of severity, information

about the situation, communication/information chain, internal actions (to the area/process), necessary resources, internal impact (to the area/process), impacts on others departments/processes, external impacts and external actions (i.e. with Customers or other stakeholders);

- Record of use of contingency plans;
- Record of review of contingency plans.

Each severity level should include the following information:

- **Situation**: description of the situation in the area, detailing and quantifying the products, items and aspects affected by the contingency situation;
- **Communication**: describes the communication chain by identifying:

  - Who should be informed and by whom (internally and externally), during the day, night, and weekend shifts and by what means;

  - Who is responsible for regularly reporting, indicating the frequency of reporting;

  - Who is responsible for escalating to the next severity level.

- **Internal actions**: describes the actions to be taken to cancel, minimise or contain the impacts in the area or process in question. Other information, such as plans that identify locations and flows, and others relevant to executing the described actions, must also be included in the annex.
- **Required resources**: information on the resources needed to deal with the contingency situation;
- **Internal impacts**: identification and quantification of impacts in the area or process;
- **Impacts on other departments/processes**: identifying and quantifying impacts on other departments or processes;
- **External impacts and external actions**: identifying and quantifying external impacts outside the organisation and identifying actions to be developed externally with OE customers and other stakeholders;
- **Recovery actions after a contingency situation**: identification of the necessary actions after the end of the contingency situation that allow the recovery of normal operations and the reprocessing of the affected products during the contingency situation, considering the feasibility of their reprocessing;
- Record of use of contingency plans.

6.3.3 Implementation of Contingency Plan Matrix

As described in 5.8, meetings were held with the multidisciplinary teams. As a result, of the contingency plans shown in figure 6.23, eight were concluded with the multidisciplinary teams. Upon completion, they were submitted for approval to the PoMS by the directors of all the departments involved. After their approval, they were published on the same platform, as seen in Figure 6.25.

	Plano de Contingência (TI) - CGRS - CST	1	Jun 6, 2022	0	
	Plano de Contingência (TI) - CGRS - PLT	1	Jun 13, 2022	0	
	Plano de Contingência (TI) - EWM - Geral	1	Jun 3, 2022	0	
	Plano de Contingência (TI) – Generalidades	2	Jun 3, 2022	0	
	Plano de Contingência (TI) - Inspeção Final e ContiSeal	1	Jun 13, 2022	0	
	Plano de Contingência (TI) - Inspecção Final- CST	1	Jun 14, 2022	0	
	Plano de Contingência (TI) - MMS and LABsystem	1	Jun 14, 2022	0	

Figure 6.25: Contingency Plans on PoMS: file and publish date

In the case of the CGMS contingency plan, as mentioned in 5.8, it was necessary to carry out simulations to verify the proposed actions. In the simulations, necessary measures were taken to ensure the proper functioning of the contingency plan. Therefore, the multidisciplinary team decided that the plan would only be submitted for approval after carrying out these actions and conducting a new simulation. Therefore, this was the only contingency plan within the scope unfinished.

Chapter 7

Conclusion

The case study's first step was evaluating the CMIP production process and the interaction of six MES systems with this process. After this analysis, for each system, was conducted the Risk Assessment. Three stages divided the Risk Assessment: Risk Identification, Risk Analysis, and Risk Evaluation.

During the Risk Identification stage, were applied several tools to identify risks, including the BIA, o Brainstorming, and structured and semi-structured interviews. After identifying the existing risks in the production process, two risk management tools were implemented during the Risk Analysis and Evaluation stages: the Risk Register and the FMEA. All the tools used to comply with the ISO 31000:2018 standard are present in the ISO 31010:2019 standard; these are in line with risk-based thinking in ISO 9001:2015, as well as IATF 16949:2016.

During the identification, analysis and assessment of the general risks of the DTI, the methodology applied was the FMEA. Furthermore, the implementation of FMEA resulted in the necessity to comply with the standards established by the DQ. While during the Risk Assessment of the MES systems, the applied methodology was the Risk Register, allowing DTI to use and maintain the documents easily. Furthermore, in order to allow easy visualisation of the results, the Risk Matrix was also used.

The application of the Risk Register brought several advantages to DTI, namely the easy visualisation and structuring for monitoring the various risks. However, it exposes the result of a subjective evaluation based on the personal evaluation of each criterion. In the case of the Risk Assessment for MES systems, this assessment depended on the LKU. The Class criterion directly depends on the Probability and Impact classification by the LKU. Therefore, the assignment of a Class parameter simplified the prioritisation process of the risk treatment. However, as shown in Chapter 6, the same Class may represent different combinations of the Probability and Impact criteria. This limitation may affect treatment actions as well as risk prioritisation. Furthermore, applying the Risk Register requires in-depth knowledge about the production system itself and the interconnection of systems, which may be a limitation if the performers are not fully involved in the assigned process or system.

Both the application of the Risk Register and the FMEA present the same limitation, the

subjectivity of criteria assignment. Furthermore, the same advantages regarding the easy visualization of the results and monitoring them. One of the critical differences between Risk Register and FMEA is the assignment of the RPN and Class criteria. While the RPN criterion used to define simulations is more comprehensive than the Class criterion, as it depends on three factors to be defined by the stakeholders. Once again, this limitation affects the priority strategy, which requires the DQ to have stipulated rules for carrying out simulations. For example, simulation planning is carried out every three years and reviewed yearly. Another disadvantage of applying the FMEA is that if the identification of possible failure modes fails, there may be risks that may go unnoticed. This limitation led to the use of the Risk Register in order to complement the information present in the CMIP contingency plan. Like the Risk Register, the FMEA exists so that stakeholders also have in-depth knowledge of the topic and activities where the technique is applied.

In short, considering that all risk management tools have advantages and disadvantages, the identified advantages justify using any of these techniques to assess and manage risk. This conclusion comes from the fact that risk management is an iterative process that must be optimised, identifying and eliminating potential risks or reducing their impact, thus reducing high and unnecessary costs.

After conducting the Risk Assessment, the necessary treatment measures were stipulated during the Risk Treatment stage. Some of these measures were the revision or creation of contingency plans, including at least the following systems: CGMS, CGRS, EWM, FFDACS, MMS and MCAT. As discussed in section 6.3, sometimes, the same contingency plan would include more than one system due to the interconnection and dependence of some systems. When verifying this interconnection, the contingency plan would relate to an area of the CMIP. For example, the MMS and LABsystem contingency plan correspond to the Mixing area. In the case of the CGRS, it was necessary to divide by factory unit since the organisational management of the units is different.

Regarding the EWM and the CGMS, it was decided with the multidisciplinary teams to carry out only one contingency plan, covering both manufacturing units. In the case of CGMS, the contingency plan divides into three processes: Preparation, Tire Building and Curing, since each process will have its specification. Unlike the other contingency plans, the multidisciplinary team chose to carry out three simulations per process to validate the defined actions. Both the Preparation and Tire Building simulations had an efficiency of 100%. However, the Curing simulation had only efficiency of 20%. Therefore, and due to the end of the internship period, completing the CGMS contingency plan was inconceivable. However, the materials for the new simulation and the topics for the next meeting were prepared in advance.

Another limitation related to creating contingency plans comes from the interconnection between contingency plans — for example, the APA contingency plan depends on both contingency

plans of Final Finishing in PLT and CST. Since the revision or creation of the Final Finishing contingency plans concluded at the end of the internship period, it was impossible to present the last proposal of the APA's contingency plan to its multidisciplinary team. Therefore, seven of the nine contingency plans were revised or created and submitted on the PoMS portal. The other two plans, one of which only needs the multidisciplinary team's approval and the other to close the actions related to the Curing process.

The deliverables of this dissertation are the results of the Risk Assessment on the indicated systems, the update on the general contingency plan and the CMIP contingency plan, and the revision or creation of seven contingency plans for the MES systems.

During the internship process, knowledge about the company was acquired, regarding production system and its relation with the information systems, which allowed the contextualisation and assessment of the existing risk in the organisation.

In conclusion, carrying out the Risk Assessment and creating contingency plans made it possible to create awareness of the systems' dependence on the production process and provide the organisation with tools that will allow the business to continue if any risks arise.

7.1 Limitations and Future Work

During this project, some limitations emerge as a result, such as:

- The FMEA methodology was only applied to the DTI process and only from the perspective of its interaction with the production process, focusing on the MES systems and not in detail on all IT systems or infrastructure;

- Still relatively to FMEA, were also experienced difficulties in calculating the RPN due to its subjectivity and because the weights used in this calculation took into account the information from the members of the DTI board, and the values of S, D and O may not represent the exact reality;

- In conducting the Risk Assessment, as a matter of time and DTI's priority, only the risks with the most significant impact on business continuity were considered. Therefore, risks may go unnoticed, given that only the input from the LKUs and the DTI was considered to carry out this Risk Assessment.

- During the contingency plan meetings, some difficulties were experienced in presenting the scenario of the contingency situation (in the worst-case scenario, it is not possible to use any of the system's features). In addition, due to the complexity of some work teams, the scheduling of meetings contributed to the lengthy process of creating contingency plans.

- Another difficulty observed was the lack of documentation related to some production systems, which impacted the first meetings with the LKUs, since it was impossible to structure the interviews similarly for all systems.

In conclusion, to improve the results of this project, the following steps and suggestions were identified:

- Completion of the APA contingency plan;
- Conduct the simulation of the CGMS failure in Curing and completion of the CGMS contingency plan;
- Monitoring the risks collected during the risk assessment, as well as creating the contingency plans referred to in 6.3;
- Conducting the Risk Assessment of other areas of the DTI.
- Creating a platform where all the risks related to the DTI are present. The platform can also be applied to risk management projects in the CMIP, condensing all the risk management information in just one application.

Appendix A

Organisational chart

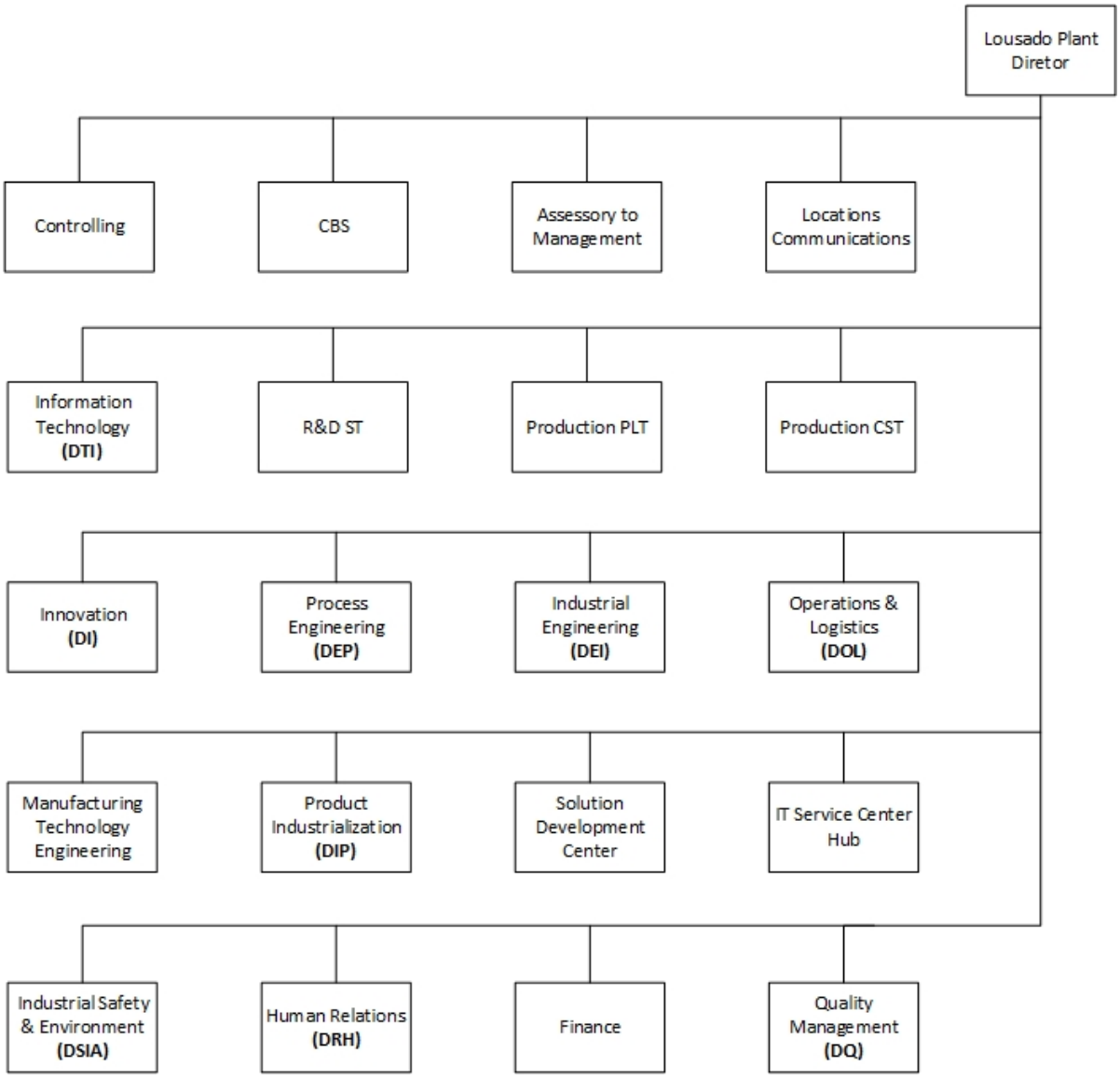

Figure A.1: Organisational Chart

Appendix B

MES Schematics

B.1 CST MES Schematic

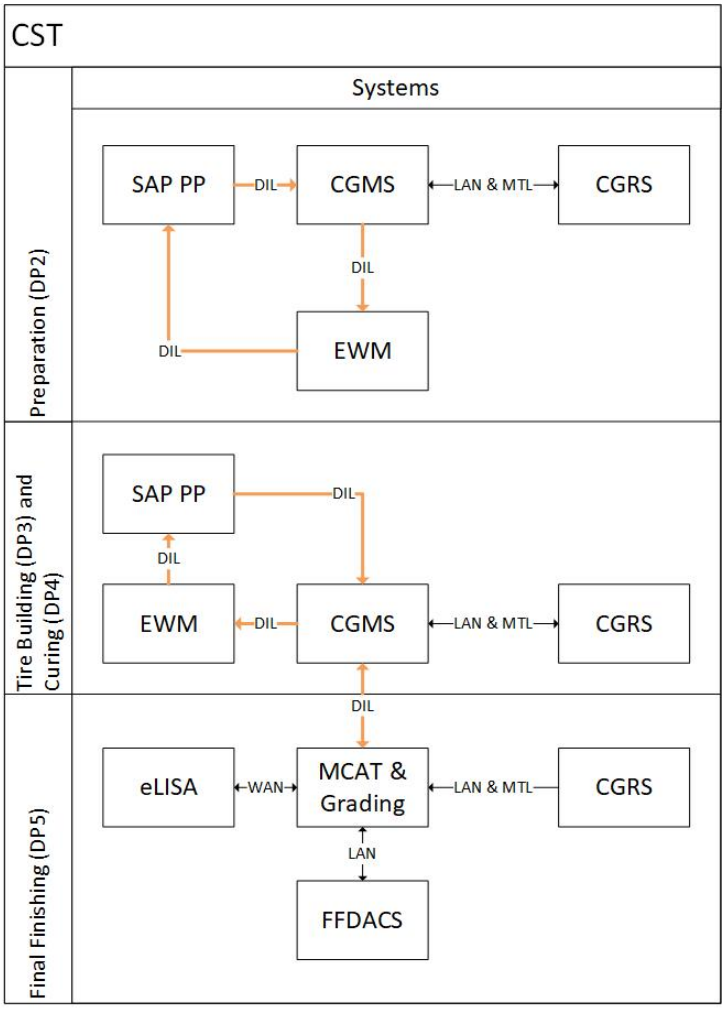

Figure B.1: CST MES Schematic

B.2 PLT MES Schematic

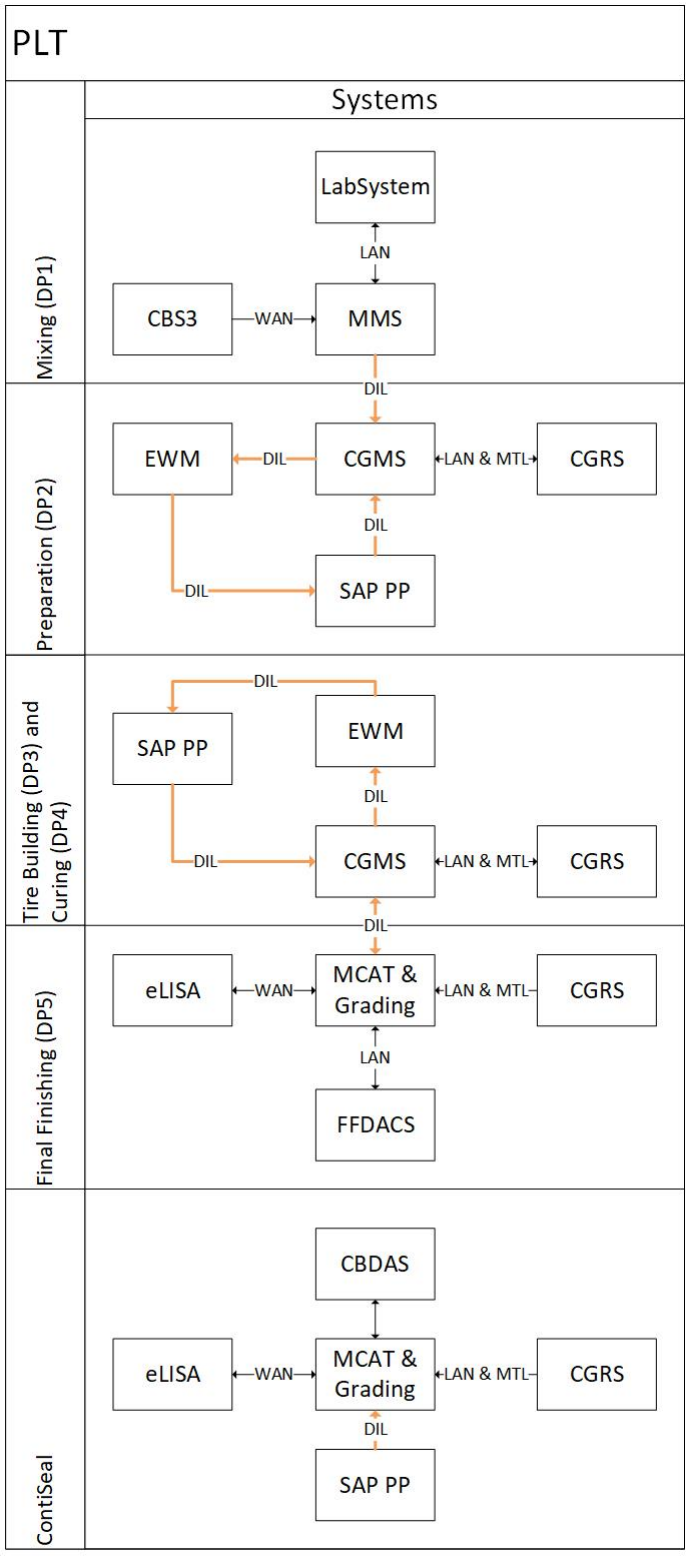

Figure B.2: PLT MES Schematic

B.3 MES Communication Schematic

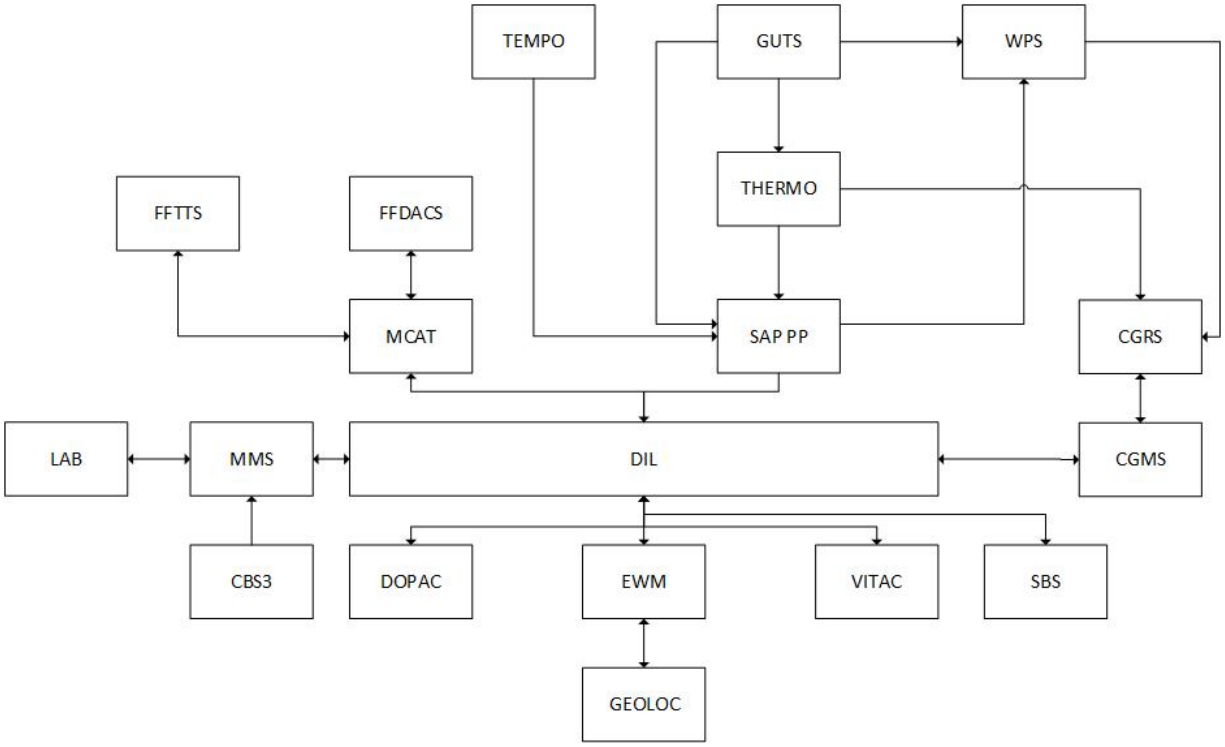

Figure B.3: MES Communication Schematic

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