



University of Minho
School of Engineering

Samuel Fernandes Silva

**Risk Management and Quality Gates
in New Product Development
projects: a case study in the
automotive industry**



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Master 's Dissertation
Master 's in Engineering and Quality Management

Dissertation supervised by
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Professor Doctor Cristina Maria dos Santos Rodrigues

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"...O fim de uma viagem é apenas o começo de outra. É preciso ver o que não foi visto, ver outra vez o que já se viu, ver na primavera o que se viu no verão, ver de dia o que se viu de noite... É preciso voltar aos passos que foram dados, para os repetir, e para traçar caminhos novos ao lado dele."

José Saramago, *Viagem a Portugal*

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A TODOS, o meu mais sincero obrigado! :)

STATEMENT OF INTEGRITY

I declare that I have acted with integrity in the preparation of this academic work and confirm that I have not resorted to the practice of plagiarism or any form of misuse or falsification of information or results in any of the stages leading to its preparation.

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Risk Management and Quality Gates in New Product Development projects: a case study in the
automotive industry

ABSTRACT

This study assesses the importance of Risk Management in New Product Development projects within the automotive industry, a sector characterized by high technical complexity and strict quality standards. In today's context, where markets are increasingly dynamic and demanding, the integration of Risk Management practices with Quality Gates proves crucial to ensuring that each phase of the project meets specific quality standards. The objective of this thesis is to evaluate how robust Risk Management practices impact quality in New Product Development projects, providing a detailed analysis of how this integration influences product outcomes and proposing improvements to address specific industry challenges. A Case Study methodology was adopted, utilizing both quantitative and qualitative data, allowing for a comprehensive view of the effectiveness of Risk Management practices. The results indicate that projects with a structured Risk Management approach exhibit higher quality indicators, with a strong correlation observed between Risk Management ratings and compliance with Quality Gates. The study concludes that effective Risk Management is fundamental to the success of New Product Development projects. Based on this, a set of improvements is proposed to enhance the organization's ability to manage uncertainties and promote project quality. The study emphasizes the importance of a cooperative and proactive approach, suggesting the creation of an organizational culture focused on risk awareness and continuous strengthening of processes and team dynamics.

Keywords: New Product Development, Quality Gates, Risk Management

Gestão do Risco e *Quality Gates* em projetos de Desenvolvimento de Novos Produtos: um estudo de caso na indústria automóvel

RESUMO

Este estudo avalia a importância da Gestão do Risco em projetos de Desenvolvimento de Novos Produtos na indústria automóvel, um setor com alta complexidade técnica e normas de qualidade rigorosas. No contexto atual, onde os mercados são cada vez mais dinâmicos e exigentes, a integração de práticas de Gestão do Risco com *Quality Gates* revela-se crucial para assegurar que cada fase do projeto cumpra padrões específicos de qualidade. O objetivo da dissertação é avaliar como é que as práticas robustas de Gestão do Risco impactam a qualidade em projetos de Desenvolvimento de Novos Produtos, oferecendo uma análise detalhada de como essa integração influencia o resultado dos produtos e propondo melhorias para enfrentar desafios específicos do setor. Adotou-se a metodologia de Estudo de Caso, com a utilização de dados quantitativos e qualitativos, permitindo uma visão abrangente sobre a eficácia das práticas de Gestão do Risco. Os resultados indicam que projetos com uma abordagem estruturada de Gestão do Risco apresentam índices de qualidade superiores, com uma forte correlação observada entre as classificações de Gestão do Risco e a conformidade com os *Quality Gates*. Conclui-se que uma Gestão do Risco eficaz é fundamental para o sucesso em projetos de Desenvolvimento de Novos Produtos. Com base nisso, o estudo propõe um conjunto de melhorias que visam fortalecer a capacidade da organização em lidar com incertezas e promover a qualidade dos projetos. O estudo enfatiza a relevância de uma abordagem cooperativa e proativa, sugerindo a criação de uma cultura organizacional focada na consciencialização dos riscos e no fortalecimento contínuo dos processos e das dinâmicas de trabalho das equipas envolvidas.

Palavras-chave: Desenvolvimento de Novos Produtos, *Quality Gates*, Gestão do Risco

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LIST OF ABBREVIATIONS AND ACRONYMS

AE	Automotive Electronics
BBM	Mobility Solutions
BG	Bosch Group
BPLM	Bosch Project Life Cycle Model
EMV	Expected Monetary Value
NPD	New Product Development
PDP	Product Development Process
PEP	Product Engineering Process
PMI®	Project Management Institute
PM	Project Management
PMBOK® Guide	Project Management Body of Knowledge
PjM	Project Manager
PLC	Project Life Cycle
QG	Quality Gate
QGC	Quality Gate Customer
RBS	Risk Breakdown Structure
RI	Risk Indicator
RM	Risk Management
RMP	Risk Management Plan
SuperOPL	Super Open Points List
SG®	Stage-Gate
SOP	Start of Production

1. INTRODUCTION

This chapter presents the background and motivation for this master's dissertation in section 1.1. Subsequently, section 1.2 outlines the research objectives, while section 1.3 details the overall methodology employed to achieve them. Lastly, section 1.4 provides a brief overview of the document's structure.

1.1 Background and Motivation

In the competitive and globalized automotive industry, organizations must continuously adapt and innovate to meet evolving market demands and remain relevant. The rapid integration of Industry 4.0 technologies has significantly heightened expectations among customers and stakeholders. They are not only concerned with the speed of delivery but also prioritize product quality and innovation (Kerzner, 2018).

This environment presents substantial challenges for New Product Development (NPD) projects. To navigate these complexities successfully, effective Project Management (PM) practices become essential. PM provides a structured approach that aligns project objectives, optimizes resource allocation, and ensures timely delivery of products (Silva et al., 2022). Within this framework, maintaining high-quality standards and effectively managing risks are critical for achieving competitive and successful outcomes in NPD (Lin et al., 2018).

Risk Management (RM) emerges as a strategic component that plays a vital role in the NPD lifecycle. By identifying and addressing potential threats early in the project, RM helps organizations reduce delays and allocate resources effectively to meet market requirements (PMI, 2017; Chapman & Ward, 2011). Furthermore, the implementation of Quality Gates (QGs) acts as an essential quality assurance mechanism. These checkpoints are established at critical phases of the project to verify compliance and quality, reinforcing a preventive and rigorous approach to project progression (Cooper, 2008).

The significance of RM and QGs is particularly pronounced in the automotive sector, where high technical complexity and stringent regulatory and safety standards shape the competitive landscape (Silva et al., 2022). Integrating these practices with robust PM strategies has been shown to positively influence project completion within planned timelines and budgets, enhancing customer satisfaction, productivity, and overall competitiveness (PMI, 2017; Ribeiro, 2018).

Therefore, this master's dissertation aims to examine the contribution of RM practices to the quality of NPD projects within the automotive industry. Through a comprehensive literature review and a focused case study, it seeks to identify critical practices, challenges, and opportunities associated with RM and QGs in the context of Industry 4.0. The insights and recommendations derived from this study will support the development of strategies that contribute to the success of automotive projects in an increasingly demanding and innovation-driven market.

1.2 Objectives

This master's dissertation investigates the contribution of RM within the scope of an NPD project. Starting from the concept of QGs as an indicator of the quality of a project, the research seeks to study the role of RM in identifying risks and opportunities for improvement throughout the different phases of NPD projects.

Given the objectives of this dissertation, the following research question has been formulated:

In the context of New Product Development, do Risk Management practices contribute to the quality of the project?

This research question guides the study and aims to clarify the relationship between RM and the quality of project outcomes, particularly in dynamic and competitive sectors such as the automotive industry. The central objective, therefore, is to explore how the adoption of robust RM practices can directly impact the quality of NPD projects. By doing so, the study seeks to promote a more structured and effective RM approach to NPD projects.

1.3 Research Methodology

A rigorous investigation must be grounded in methodologies that validate both the procedures and results, making the selection of methodology a critical step in any research project. These methodologies ensure the credibility of the research process and provide a framework for achieving defined objectives. Therefore, choosing an appropriate methodology requires thorough reflection and careful consideration by the researcher (Carvalho, 2017).

Saunders, Lewis, and Thornhill (2009) describe the research process through the **Research Onion** diagram, which encompasses essential aspects such as research philosophies, approaches, strategies, choices, time horizons, techniques, and procedures. This structured approach, illustrated in Figure 1,

ensures that every component of the research process is thoroughly defined, and that the chosen methodology aligns well with the research questions and objectives.

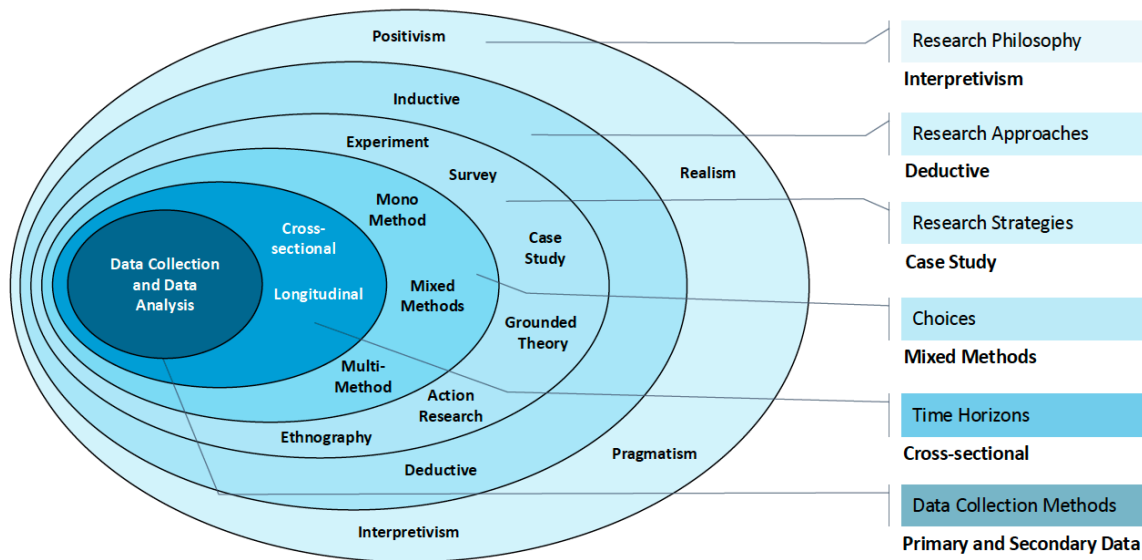


Figure 1: Research Onion Model in this Master 's Dissertation (Adapted from Saunders et al. (2009))

The outermost layer of the Research *Onion* represents the **Research Philosophy**, which determines the investigator's experience in the development of knowledge and relates to a specific subject matter.

- i. **RESEARCH PHILOSOPHY:** The research philosophy adopted is **Interpretivism**, an epistemology that emphasizes understanding the differences between individuals as social actors. This philosophy views reality as subjective, open to multiple interpretations and meanings. The aim of interpretive research is to develop richer understandings and interpretations of social worlds and contexts (Saunders et al., 2009).
- ii. **RESEARCH APPROACH:** In this master's dissertation, a **Deductive Approach** was chosen. According to Saunders et al. (2009), this approach is appropriate when the goal is to collect data to support the author's hypothesis through the selected research strategy.
- iii. **RESEARCH STRATEGY:** The selected strategy is the **Case Study**, which, according to Yin (2014), is especially relevant when the goal is to explain a contemporary social phenomenon, such as understanding the "how" or "why" behind it. This approach is well-suited for investigating situations in their real-life contexts. It can also complement other research methods, allowing the researcher to propose new practices based on comprehensive insights.
- iv. **CHOICES:** This research used a **Mixed-Methods** approach. According to Saunders et al. (2009), qualitative data were used to interpret reality as it is, while quantitative data served

hypotheses through structured data collection and analysis. This combined approach provided a comprehensive understanding of the research problem, supported by diverse insights.

- v. **TIME HORIZON:** This project's timeline aligns with the duration of the company's curricular internship, allowing it to be considered a **Cross-Sectional** study.
- vi. **DATA COLLECTION AND ANALYSIS:** The final layer of the Research Onion addresses the techniques and procedures for gathering and analyzing information crucial to the research project. According to Yin (2014), case study research may rely on six primary data sources: internal and external documentary analysis, participant observation, data extraction, questionnaires, and unstructured interviews. Each source has limitations, so selecting the most suitable depends on the study's objectives, available resources, and the case's specific characteristics. Thoughtful selection and use of these techniques and procedures are essential to strengthen the reliability and depth of the research findings.

In this master's dissertation, both **Primary** and **Secondary Data** were utilized. Primary data were gathered through direct observation within the research environment and data extraction during the internship, providing firsthand insights. Secondary data, drawn from company documents and external sources, offered additional perspectives (Saunders et al., 2009). Combining these data sources gave the researcher a well-rounded understanding of the research problem, contributing to a more comprehensive analysis.

1.4 Structure of the Dissertation

Alongside the Introduction, the document is divided into 5 Chapters: *Literature Review*, *Case Study*, *Initial Situation Analysis*, *Proposal for Improvements*, and *Final Considerations*.

Chapter 2 of this master's dissertation provides a comprehensive literature review on PM within the context of the NPD process, with a specific focus on QGs and RM. It begins with a general contextualization of PM, emphasizing its significance in NPD projects. The chapter then delves into the NPD process, highlighting the role of QGs and their integration with PM practices. Finally, it explores the RM knowledge area, detailing its standard processes and phases, thereby offering a thorough understanding of how these components interact to enhance project outcomes.

Chapter 3 provides a comprehensive analysis of the case study, starting with an overview of the research context and methodology utilized in the study. It then examines Bosch's PM approach to RM and QGs

within the organization. The chapter focuses on a specific NPD project, delivering an in-depth evaluation of RM's current practices, dynamics, and routines.

In Chapter 4, an initial examination of the RM practices within the case study is undertaken. Furthermore, a thorough investigation is conducted using a selection of projects to address the proposed research question. This analysis reveals the key factors contributing to the inefficiency of RM practices, providing valuable insights for potential improvements.

Building on the findings from the analysis conducted in Chapter 4, Chapter 5 presents a series of practical recommendations to enhance RM in NPD projects to improve the outcomes of the QGs assessments.

Finally, Chapter 6 presents the final considerations of the master's dissertation, summarizing the key findings, implications, and contributions of the research and suggesting directions for future work in this field.

2. LITERATURE REVIEW

This chapter establishes the theoretical foundation for the case study by reviewing key concepts that are essential for a comprehensive understanding of the research topic. To ensure a robust and multidisciplinary perspective, a diverse range of articles, books, and other credible sources were meticulously selected and analyzed, thereby expanding and deepening the scope of the investigation.

The primary reference for this study is the Guide to the Project Management Body of Knowledge (PMBOK® Guide), developed by the Project Management Institute (PMI®). This guide serves as the primary reference, aligning closely with the practices observed within the organization under study. The PMBOK® methodologies are highlighted for their enduring relevance and effectiveness in promoting structured and efficient PM practices.

The chapter is systematically organized into four main sections, each addressing a critical dimension of project development. Section 2.1 delves into the complexities of New Product Development, focusing on fundamental concepts within the field of Project Management. Section 2.2 explores the concept of Quality Gates, underscoring their pivotal role in ensuring quality control and optimizing the New Product Development process. Section 2.3 examines the principles of Risk Management, emphasizing its importance as an integral component of both Project Management and New Product Development. Finally, section 2.4 consolidates the findings from the literature review, synthesizing the core theoretical insights that underpin the research question and inform subsequent analyses.

2.1 New Product Development

In today's fast-paced environment of change and innovation, PM has become an indispensable tool for organizations aiming to develop new products and sustain a competitive advantage. By implementing effective management practices, companies can optimize resources and harness their teams' creative potential, resulting in innovative solutions that align with market demands (Guerra et al., 2016). NPD plays a vital role in organizations by fostering opportunities for innovation and growth, creating a sustainable competitive edge, and enhancing brand image (Pons, 2008).

According to the PMBOK® Guide, NPD projects are temporary endeavors with a defined start and end, specifically aimed at producing unique products or services (PMI, 2017). In this context, a new product refers to a concept or offering that is entirely new to either the market or the organization, even if similar

products already exist. Introducing such products demands meticulous planning and execution due to the inherent complexities of developing innovative solutions (Panwar & Bapat, 2007).

The importance of NPD has grown significantly in recent decades, driven by rapid technological advancements, evolving customer needs, and increasingly shorter product life cycles. These dynamics place considerable pressure on companies to meet tight deadlines, stay within budget, and achieve performance goals (Drennan, 1990). Successful NPD requires effective collaboration among teams and strong communication with stakeholders to ensure alignment with project objectives and deliver a final product that meets market expectations (PMI, 2017).

This master's dissertation centers on developing a tailored product for a single client, an approach particularly advantageous for companies operating in niche markets. Customizing products to meet a client's specific needs allows for highly specialized solutions but also introduces additional complexities. Achieving success in this context requires rigorous planning, precise execution, and close attention to detail (Kara & Kaynak, 1997).

2.1.1 Project Management Evolution

PM has deep historical roots, as evidenced by ancient large-scale projects such as the Pyramids of Giza and the Great Wall of China, where fundamental principles of planning, organization, and control were already applied (Kwak, 2005; Seymour & Hussein, 2014). Over time, PM has developed into a formal discipline, particularly in the modern era, influenced by technological advancements, evolving business practices, and an increasing focus on collaboration, adaptability, and continuous improvement (Kerzner, 2017).

The formalization of PM has been significantly shaped by global organizations. Notable contributions include the establishment of the International Project Management Association in 1965, the Project Management Institute (PMI®) in 1969, and the Association for Project Management in 1972. Among these, the PMI has played a pivotal role by standardizing methodologies and publishing the PMBOK® Guide, which has become a globally recognized reference in the field.

Despite its considerable advancements, the implementation of PM continues to face persistent challenges, including resistance to change, insufficient support from senior management, and the complexities of integrating diverse methodologies (Kerzner, 2017). Addressing these challenges requires strong organizational commitment and a strategic approach to adapt PM practices to the specific characteristics of each project. Since no two projects are identical, there is no universal process that

guarantees success in every scenario (Ahlemann et al., 2009). As a result, the Project Manager (PjM) must tailor best practices to suit the unique context of each project, while also considering cultural differences that can influence project dynamics and outcomes (Ilies et al., 2010).

The growing importance of PM in the business world is driven by technological innovations, shifts in business environments, and an increasing need for flexibility and collaboration (Kerzner, 2017). These factors have empowered PjMs to deliver high-quality projects more efficiently, within shorter timeframes, while simultaneously creating significant value for their organizations (PMI, 2021).

2.1.2 Project Definition

To fully understand the field of PM, it is essential to define the concept of a project. According to the PMBOK® Guide, a project is defined as "a temporary endeavor undertaken to create a unique product, service, or result" (PMI, 2021, p. 4). This definition emphasizes the temporary nature of projects, which are characterized by a defined start and end, a specific scope, and allocated resources.

A project is considered complete when its objectives are either achieved or when it is closed without meeting them. Closure may occur for various reasons, such as the inability to meet the goals, a change in the project's necessity, or a decision by stakeholders (PMI, 2021). Moreover, each project is unique, defined by a specific set of tasks designed to achieve a particular objective, distinguishing it from ongoing processes (Miguel, 2019).

Over time, various definitions of a project have been proposed, each highlighting different aspects of its nature. Despite the differences in terminology, these definitions share several essential characteristics that are crucial to understanding the concept. According to PMI (2017), the primary characteristics of a project are illustrated in Figure 2.

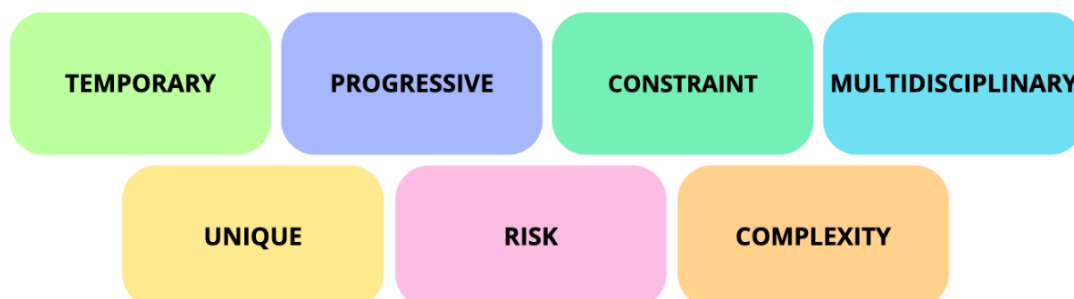


Figure 2: Key Characteristics of a Project

As illustrated in Figure 2, every project is temporally distinct, characterized by a clearly defined beginning and end, which differentiates it from ongoing operations. Its uniqueness arises from its specific attributes,

which contribute to the creation of a unique product, service, or result. Furthermore, projects are progressive in nature, with greater clarity regarding their scope and details emerging as they evolve (PMI, 2017).

Inherently complex, projects consist of interdependent tasks and resources that require careful coordination and management. They are constrained by time, cost, and resource limitations, which necessitate the application of effective management strategies. Additionally, all projects face risks stemming from uncertainties and potential changes, demanding proactive measures to anticipate and mitigate these challenges (PMI, 2017).

The multidisciplinary nature of projects further highlights the need for collaboration across various areas or organizations to ensure successful outcomes. Together, these characteristics underscore the critical role of PM in navigating complexities and addressing the challenges inherent in project execution (Baker, 2010; PMI, 2017).

2.1.3 Project Management Concepts

According to the PMBOK® Guide, PM is a structured and temporary process designed to deliver a unique product, service, or result (PMI, 2021). Its primary goal is to achieve the project's objectives while addressing the expectations of all stakeholders (Sidorov & Senchenko, 2020). To achieve success, the execution and delivery of a project must be well-organized and managed effectively across three critical constraints: **time**, **cost**, and **scope**.

These three constraints are traditionally represented by the **Project Management Triangle**, a model that illustrates their interconnection and influence on project outcomes. Effectively managing time, cost, and scope is essential to ensure the overall success of the project (Ward, 2003; Marchewka, 2006; Campbell & Baker, 2007; Dobson & Feickert, 2007; PMI, 2021).

The time dimension relates to scheduling and project duration, including deadlines and milestones. Efficient planning and time management strategies are crucial to meet these requirements. The cost dimension involves budgeting and resource allocation, requiring rigorous oversight to prevent budget overruns and maintain profitability. The scope dimension defines the project's requirements and deliverables, ensuring alignment with stakeholder expectations and project objectives (Ward, 2003; Marchewka, 2006; Dobson & Feickert, 2007).

As illustrated in Figure 3, a project can be conceptualized as a three-dimensional entity, where time, cost, and scope collectively shape stakeholder expectations and determine the quality of the final deliverable.

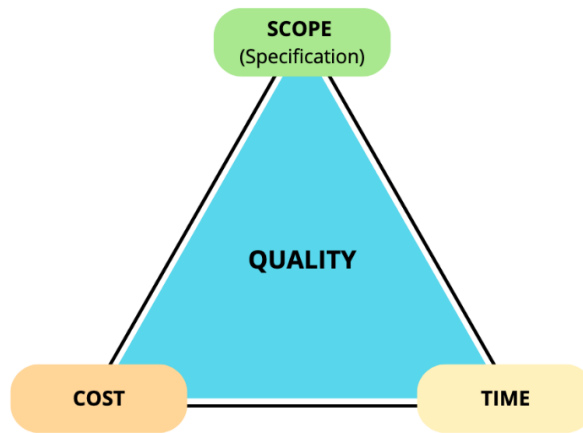


Figure 3: Project Management Triangle (Adapted from Atkinson (1999))

The interplay among time, cost, and scope is crucial for measuring project success, which is defined as the ability to meet specific objectives (scope) while adhering to delivery timelines (time) and efficiently utilizing available resources (cost). Quality is an integral component of PM, intrinsically linked to the balance of these three constraints (Flett, 2001; Dobson & Feickert, 2007; Burke, 2007; PMI, 2021).

The Project Management Triangle serves as a visual representation of the relationship between these constraints, emphasizing that any change in one dimension inevitably impacts the others (Newell & Grashina, 2003; PMI, 2021). Together, these dimensions shape project outcomes and influence the overall quality of the final deliverable (Dobson, 2004).

In this context, the Project Management Triangle is an invaluable tool for the PjM, as it supports effective RM and enhances adaptability in the face of change. By helping to identify and prioritize project needs, it fosters clear and transparent communication with stakeholders. When these elements are managed efficiently, the likelihood of delivering a high-quality final product is significantly increased (PMI, 2017).

2.1.4 Project Life Cycle

According to the PMBOK® Guide, the Project Life Cycle (PLC) is defined as “the series of phases that a project goes through from its start to its completion” (PMI, 2021, p. 716). Each phase within the PLC involves a specific set of logically related activities aimed at fulfilling project requirements and meeting delivery timelines (PMI, 2021).

These phases may follow a sequential, iterative, or overlapping progression, offering the flexibility to meet the unique needs and characteristics of each project. Despite variations in size and complexity, the fundamental structure of the PLC remains consistent. As illustrated in Figure 4, the PLC consists of generic phases that guide the project from initiation through to completion.

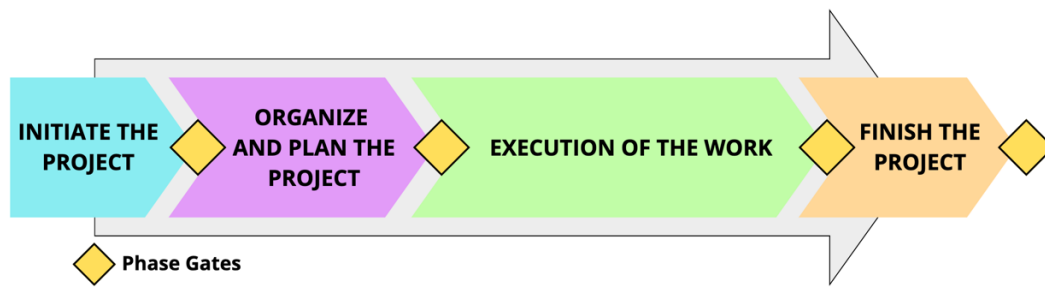


Figure 4: Generic Phases of the PLC (Adapted from PMI (2021))

The completion and approval of specific deliverables marks a project phase. For instance, the first phase typically involves developing the **Project Charter**¹, while the subsequent phase focuses on creating the **Project Management Plan**², which serves as the foundation for project execution. Each phase concludes with control points, where the project's performance is evaluated against the project documents, and these evaluations determine whether the project will proceed (PMI, 2017). While this structure provides a foundational framework applicable to any project, it must be flexible enough to accommodate the variety of factors specific to each project.

The management of the PLC is conducted through a series of activities known as **Process Groups**. Each process group involves a specific set of activities carried out by the project team, stakeholders, and other relevant parties to ensure the project is completed within the three constraints (PMI, 2017), as explained earlier in subsection 2.1.3. Although there are different ways to organize these processes, PMI (2017) classifies them into five Process Groups, described below and presented in Figure 5.

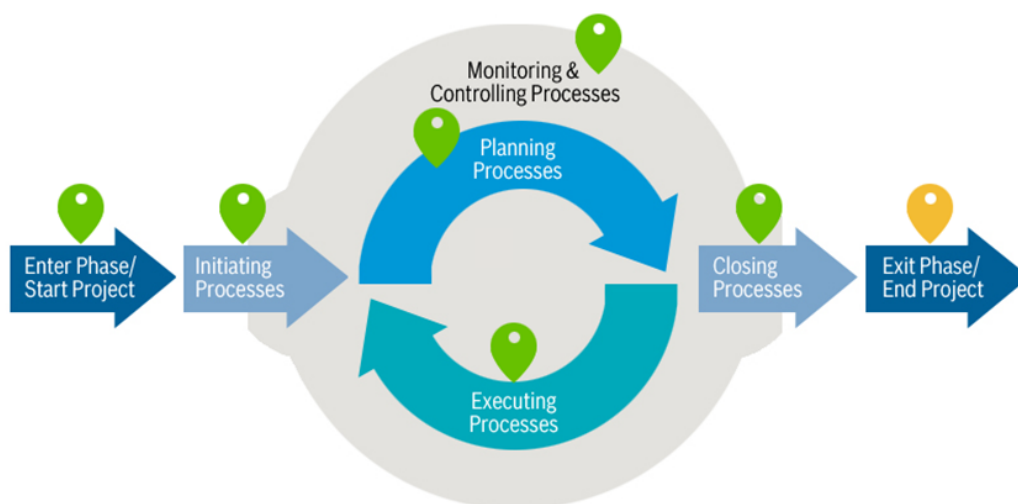


Figure 5: Process Groups in Project Management (PMI, 2017)

¹ Document that formally authorizes the existence of a project and grants the PjM the authority to allocate resources to project activities.

² Document that describes how the project will be executed, monitored, and controlled.

- i. **INITIATING PROCESSES:** Responsible for obtaining authorization to start a new project or phase, including developing the Project Charter, which formalizes the project and identifies stakeholders.
- ii. **PLANNING PROCESSES:** Involves defining the project scope, detailing objectives, and creating an action plan to achieve these objectives, ensuring comprehensive consideration of all project aspects.
- iii. **EXECUTING PROCESSES:** This process focuses on completing the work defined in the Project Management Plan, including coordinating people and resources.
- iv. **MONITORING AND CONTROLLING PROCESSES:** Track project progress, review performance, and identify necessary adjustments, ensuring adherence to the Project Management Plan.
- v. **CLOSING PROCESSES:** Responsible for formally closing the project or phase, including delivering results and documenting Lessons Learned.

Figure 6 illustrates how the Process Groups interact and the level of overlap at different times in a project. If the project is divided into phases, the Process Groups interact within each phase and may also overlap with project phases

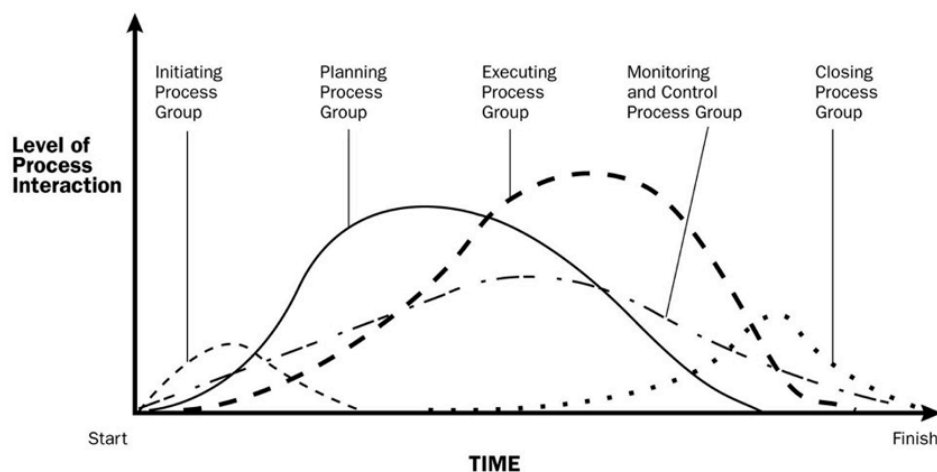


Figure 6: Process Groups Interaction (PMI, 2017)

It is crucial to understand that the Process Groups are distinct from the project itself. These Process Groups interact throughout the various phases of the PLC, and all types of processes can occur within a single phase. Moreover, processes may be repeated or interact based on the project's requirements (PMI, 2017). A comprehensive understanding and effective application of the PM Process Groups are vital for project success (Larson & Gray, 2021).

2.1.5 Project Management in NPD

In the context of NPD, PM is essential for optimizing resources and maximizing the creative potential of teams, leading to innovative solutions that meet market demands (Guerra et al., 2016). A recent PMI study highlights that organizations adopting effective PM practices can reduce financial waste by up to 28 times, significantly lowering the risk of project failures (PMI, 2021).

Effective PM is critical to the success of NPD in today's volatile and highly competitive business environment. The ability to innovate swiftly and efficiently has become a crucial strategic advantage (Cooper & Kleinschmidt, 1987; Crawford, 1994; Eppinger & Ulrich, 2011). However, NPD projects are inherently risky, and inadequate RM can jeopardize both project outcomes and organizational competitiveness. The unpredictable nature of modern markets further amplifies the necessity for robust RM strategies, particularly in areas such as quality, pricing, and time-to-market (Kwak & LaPlace, 2005).

In NPD, effective risk identification and mitigation require detailed planning and a robust management process to ensure that new products are developed within the established timeframes and budgets without sacrificing quality or innovation (Mu et al., 2009). PM plays a vital role in this process by providing the necessary structure to coordinate and optimize all phases of product development, from the initial concept to market launch. A well-structured management plan enables a company to respond rapidly to and anticipate challenges, effectively allocating resources and making informed decisions that minimize risks and maximize opportunities for success (Cooper, 2008; PMI, 2021).

As outlined by Kowan & Rasli (2011) and PMI (2017), the NPD process can be divided into five key stages, aligned with the PM Process Groups discussed earlier in subsection 2.1.4. These stages are summarized below and represented in Figure 7.

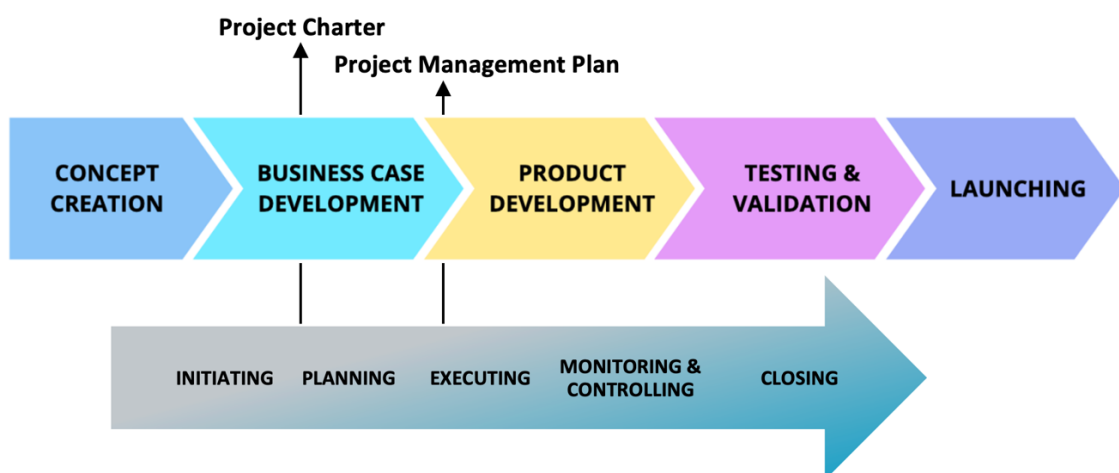


Figure 7: Stages of the NPD Process aligned with PM Process Groups (Adapted from PMI (2021))

- i. **CONCEPT CREATION:** This initial stage involves idea generation and conducting a preliminary analysis of the project. Activities such as brainstorming, and market research are employed to identify potential opportunities.
- ii. **BUSINESS CASE DEVELOPMENT:** At this stage, a detailed investigation is carried out to justify the project's viability. A business case is developed, providing the rationale for the project, including a clear product definition and a thorough cost-benefit analysis.
- iii. **PRODUCT DEVELOPMENT:** This phase focuses on designing the product and developing the production processes. Activities include technical design and prototype development.
- iv. **TESTING AND VALIDATION:** This stage involves testing the product to ensure it meets technical and market requirements and validating its readiness for launch.
- v. **LAUNCHING:** The final stage includes introducing the product to the market, with activities related to marketing, distribution, and sales strategies.

Each of these phases demands rigorous planning and coordinated execution. PM plays a central role in ensuring that the objectives related to quality, time, and cost are balanced throughout the NPD process.

The Product Development Process (PDP), illustrated in Figure 8, represents a systematic approach that companies use to transform concepts into market-ready products (Eppinger & Ulrich, 2011). The third stage in the NPD process, Product Development, aligns directly with the PDP, highlighting its significance. By implementing a structured PDP, organizations can effectively apply PM principles throughout the various stages of NPD.



Figure 8: Product Development Process (Adapted from Cooper (2008))

The seamless integration of PM principles within the NPD process is essential for achieving organizational success in today's dynamic and competitive business environment. Among the various stages, the product design phase holds particular significance, as it determines nearly 85% of the total PLC costs (Rozenfeld et al., 2006). By adopting a standardized structure in the PDP, organizations can clearly outline the stages of NPD, ensuring that each phase is executed effectively while adhering to quality, cost, and time constraints (Sanongpong, 2009).

Organizations that embrace a structured and collaborative approach to the PDP are better positioned to optimize workflows, accelerate time-to-market, and mitigate risks associated with delivery delays (Nicholas & Steyn, 2012; Costa et al., 2017). This underscores the critical role of continuously refining PM practices, empowering companies to adapt to shifting market demands and sustain a competitive advantage.

2.2 Quality Gates in NPD

The Quality Gate (QG) concept originated in product development processes, particularly within the automotive industry, as a mechanism for quality control. Over time, its application has expanded across various industries to support both product quality and effective PM practices (Ambartsoumian et al., 2011). While QGs can function independently, they are often associated with the Stage-Gate® (SG) System - a methodology derived from NASA's Phased Project Planning approach developed in the 1960s (NASA, 1968).

In the context of NPD, QGs are vital for fostering innovation and sustaining a competitive advantage. By establishing defined checkpoints, QGs allow organizations to continuously monitor and ensure quality throughout each development phase. These gates act as control points, requiring specific criteria to be met before advancing to subsequent stages. The implementation of QGs not only mitigates risks but also improves communication and ensures that product outcomes align with the organization's strategic objectives (Cooper, 2008).

2.2.1 Milestones and Stage-Gate System in NPD

The NPD process is crucial for driving innovation and maintaining competitive advantage. One widely adopted framework for managing NPD projects is the SG® System, introduced by Robert G. Cooper in the late 1980s (Cooper, 2008). This system organizes the NPD process into distinct **phases**, each aiming to achieve specific objectives, providing a foundational framework for customized models to develop (Cooper, 1990).

As illustrated in Figure 9, the SG® System incorporates decision points known as **gates**, where gatekeepers evaluate project progress based on predefined criteria to determine whether the project should proceed. This structured approach improves resource allocation and RM by ensuring that only projects meeting established standards advance to the next phase. Additionally, it helps teams navigate

the journey from concept to product launch while maintaining a strong emphasis on quality (Cooper, 2008).

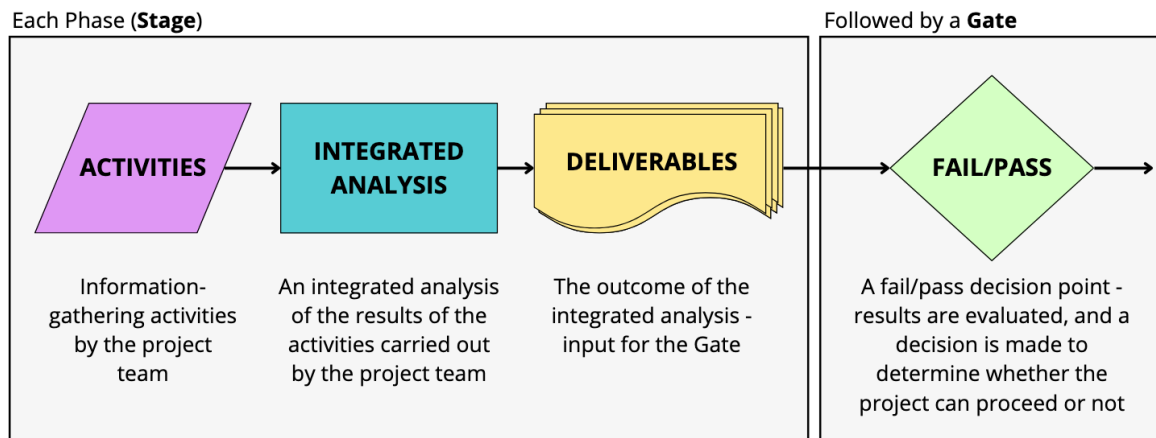


Figure 9: Decision Process of the Stage-Gate® System (Adapted from Cooper (2008))

As shown in Figure 10, the SG® System typically divides the NPD process into five sequential stages, each separated by gates. This structure identifies risks early and allows for timely adjustments, promoting continuous improvement throughout the PLC (Krishnan & Ulrich, 2001).

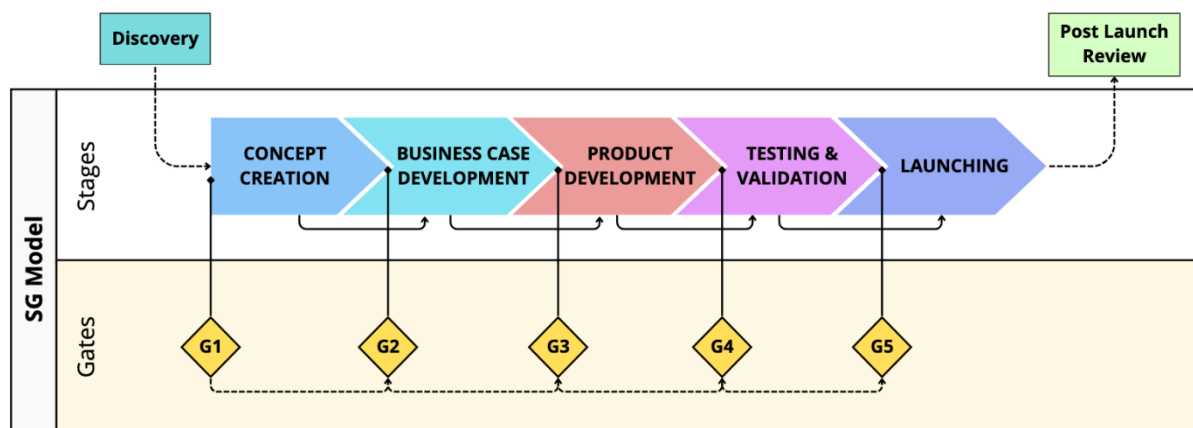


Figure 10: Stage-Gate® System in the NPD Process (Adapted from Cooper (2008))

While the SG® System is valued for its systematic approach, it has been criticized for its potential rigidity. Critics argue that this rigidity can limit adaptability, making it difficult to respond to dynamic market conditions or technological advancements (Sethi & Iqbal, 2008). In some cases, teams may feel pressured to "freeze" product specifications prematurely to meet gate criteria, even when new insights could justify adjustments (Krishnan & Bhattacharya, 2002). This lack of flexibility can be particularly harmful in projects requiring radical innovation, where adaptability is crucial (Cooper, 2008; Ettlie & Elsenbach, 2007).

In this context, **milestones** play a critical role. Unlike gates, which involve decision-making, milestones mark key points within each phase, serving as progress indicators and confirming the completion of intermediate objectives (Cooper, 2016). Tracking milestones provides teams with greater visibility and control over the project's direction, helping them stay aligned with the final objectives (Charvat, 2003; Schneider, 2004; PMI, 2017).

2.2.2 Definitions and Assessment Framework

QGs are predefined checkpoints within the PLC designed to verify if specific criteria have been met before advancing to the next phase. Their primary purpose is to ensure that deliverables meet quality standards, helping to reduce risks and improve project outcomes (Hawlitzky, 2002; Pfeifer & Schmidt, 2003; Cooper, 2008). Each QG marks a transition between project phases and provides an opportunity for thorough assessment and reflection. During these checkpoints, project teams rigorously evaluate progress, identify any deviations or risks, and define corrective actions when necessary (Flohr, 2008).

In practice, QG assessments are often facilitated by a method known as the **traffic light system**, introduced by Daimler (2003). This method uses a color-coded approach to classify the project's progress at each gate, providing a clear indication of the project's compliance with established criteria, as shown in Table 1.

Table 1: Quality Gates Assessment Criteria Rating

CRITERIA RATING	DESCRIPTION
● Red (R)	Criteria cannot be fulfilled, even with additional measures.
● Yellow (Y)	Criteria are currently not fulfilled, but agrees measures are in place to achieve compliance upon implementation.
● Green (G)	Criteria are fully met, requiring no further action.

Essentially, a QG signals the formal conclusion of a phase, with progression determined by predefined exit criteria. These criteria ensure that all necessary deliverables and quality standards have been met before moving on to the next phase. In some cases, the performance at previous QGs is also considered, ensuring interconnection between project phases and allowing for the identification of any potential issues or risks that could impact future progress (Cooper et al., 2002; Pfeifer & Schmidt, 2003; Cooper, 2008).

2.2.3 Benefits and Challenges of Quality Gates

The adoption of QGs in PM establishes a structured framework that significantly improves project quality and mitigates risks. By creating clear checkpoints throughout the PLC, QGs ensure that deliverables are evaluated against predefined criteria. This proactive approach allows quality issues to be identified and resolved early in the process, preventing problems from escalating as the project advances (Younack, 2010; Charvat, 2010).

As shown in Table 2, the key benefits of QGs, as outlined by Charvat (2010) and Younack (2010), emphasize how these quality control measures contribute to successful project outcomes.

Table 2: Benefits of Quality Gates

BENEFIT	DESCRIPTION
Improve Quality Control	QGs establish structured checkpoints for evaluating deliverables, ensuring early identification of quality issues.
Reduce Project Risks	The requirement to meet criteria before moving forward minimizes risks, preventing problems from escalating later.
Improve Communication	Regular review opportunities increase communication among teams, fostering collaboration and efficient issue resolution.
Quality Focus	Dedicated quality reviews at critical points maintain a sustained focus on high standards throughout the project.
Shared Responsibility	Involving multiple stakeholders in the review process promotes accountability and investment in project outcomes.

Despite these advantages, implementing QGs can present challenges, particularly in complex organizational settings. Defining clear entry and exit criteria for each gate requires significant coordination among diverse teams. Achieving alignment on these standards can be difficult when different departments have conflicting priorities or interpretations of quality (Pfeifer et al., 2004; Cooper, 2008).

Beyond ensuring quality and facilitating decision-making, QGs provide more robust organizational benefits. They enable continuous improvement by allowing teams to initiate corrective actions based on lessons learned, thus preventing similar issues in future projects. Additionally, organizations can assess process efficiency by identifying projects with recurring negative QG ratings. This allows them to target specific areas for improvement, ultimately enhancing future project outcomes (Cooper et al., 2002; Chao & Ishii, 2004).

Overall, QGs are not only vital control mechanisms but also strategic tools that contribute to project success through enhanced governance, RM, and effective management practices (Unger & Ppinger, 2011). By providing a structured approach for ongoing evaluation, QGs help organizations streamline their project execution and achieve desired results more consistently.

2.3 Risk Management

RM is defined as "the sum of all processes related to identifying, analyzing, and responding to uncertainties to maximize positive outcomes and minimize negative ones" (Mirboroon & Razavi, 2020, p. 43). In PM, RM plays a crucial role in ensuring project success by systematically addressing uncertainties that may impact objectives. By formalizing RM within the project environment, organizations can better navigate complexities and make informed decisions (PMI, 2021).

Projects inherently introduce changes and uncertainties, making adopting a consistent RM approach essential. This approach should ensure clear and open communication of risks throughout the PLC (Miguel, 2019). Effective RM goes beyond risk mitigation, as it also involves leveraging opportunities for project improvement (PMI, 2017). As highlighted by studies from Chapman & Ward (2004) and Aloini et al. (2012), RM supports strategic decision-making and enhances confidence in achieving project goals by reducing the likelihood of unexpected events such as delays, scope changes, or budget overruns.

Historically, risks were predominantly viewed as negative factors associated with project failure (Miles & Wilson, 1998; Padayachee, 2002). However, the modern perspective on RM recognizes the dual nature of risks, acknowledging that they can also represent opportunities. This shift in viewpoint is crucial since RM aims to mitigate negative impacts and capitalize on the opportunities that may arise throughout the project (Mirboroon & Razavi, 2020).

Consequently, RM becomes a vital PM component, supporting risk identification and management throughout the PLC (Del Caño & De La Cruz, 2002; PMI, 2017). By integrating RM into the PM framework, organizations can better prepare for uncertainties and enhance their chances of project success.

2.3.1 Framework, Definitions and Processes

Risks are defined as "undesirable events capable of causing delays, excessive costs, or unsatisfactory results for the organization, society, or the environment" (Shenhar et al., 2002, p. 102). However, the PMBOK® Guide expands this definition, describing risk as "an uncertain event or condition that, if it occurs, can have either positive or negative effects on one or more project objectives, such as cost, scope,

and quality" (PMI, 2021, p. 122). This broader perspective underscores that risks are not inherently negative and can also present opportunities. Therefore, RM is essential for minimizing potential threats while maximizing opportunities that benefit the project (Mirboroon & Razavi, 2020).

According to PMI (2021), risks can arise from multiple causes, such as assumptions, constraints, or preexisting conditions, and if they occur, they can lead to a range of impacts. Understanding the relationship between the cause of a risk, the event triggered by that risk, and the subsequent effect on the project is critical for effective risk analysis and response planning.

This relationship is visually represented in Figure 11, illustrating how different causes can lead to events that significantly impact project outcomes. The structured identification and management of risks enable project teams to anticipate challenges and better prepare for potential impacts.



Figure 11: Cause, Event, and Effect of a Risk (Adapted from OGC (2009))

To be effective, RM should be a continuous and systematic process throughout the PLC. Its objective is proactively identifying, assessing, and controlling risks that may affect deliverables and outcomes (OGC, 2009). The latest editions of the PMBOK® Guide outline a structured RM approach applicable at all project phases, encompassing seven essential processes defined by PMI (2017). These processes are illustrated in Figure 12 and will be described in detail in the following subsections.

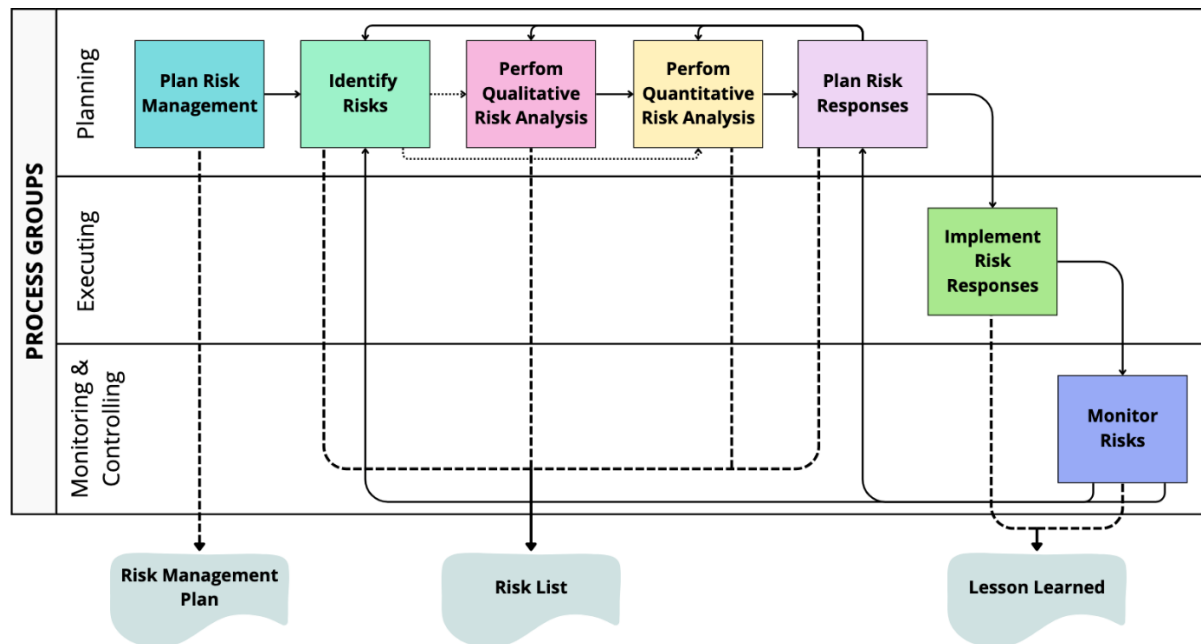


Figure 12: RM Process aligned with PM Process Groups (Adapted from PMI (2017))

As depicted in Figure 12, RM processes are structured in an iterative and cyclical manner. This cycle encompasses continuous risk identification, analysis, response planning and implementation, as well as ongoing monitoring throughout the PLC (PMI, 2017). Each iteration builds upon the previous one, refining and enhancing previous processes while incorporating improvements based on lessons learned and adjustments to the evolving project environment. This dynamic and adaptive approach allows project teams to continuously refine their RM practices, respond effectively to changing circumstances, and capitalize on emerging opportunities (PMI, 2017; Miguel, 2019).

2.3.2 Risk Management Planning

Planning for RM is a critical phase in the PM process, as it outlines how RM activities will be conducted throughout the PLC. The primary objective is to create the appropriate approach for undertaking RM activities for a project (PMI, 2017). This includes defining clear goals, outlining the scope of RM activities, and identifying the stakeholders who will be involved in the process.

A key deliverable of the risk management planning phase is the **Risk Management Plan** (RMP), which outlines the approach and processes for managing risks throughout the project. As highlighted by PMI (2017) and Miguel (2019), the RMP should address a comprehensive set of topics to ensure that risks are effectively identified, assessed, and managed. These topics are detailed in Table 3, which serves as a guide to developing a robust and adaptable RM strategy tailored to the specific needs of the project.

Table 3: Key Components of the RMP

TOPIC	DESCRIPTION
Methodology	Outline the tools and data sources for risk identification, as well as qualitative and quantitative assessments.
Risk Categories	Develop a Risk Breakdown Structure (RBS) for comprehensive identification of opportunities and threats.
Scales	Create appropriate scales for assessing probability and impact, to be used in risk analysis.
Roles & Responsibilities	Specify the RM team members and their assignments to specific work packages, tasks, categories, or risks.
Budgeting	Detail how RM considerations and risk response costs will be incorporated into the project budget.
Planning	Schedule the frequency and timing of RM activities throughout the PLC.
Formats & Templates	Establish a format for representing and visualizing risks to streamline the prioritization process.
Monitoring	Define methods for tracking identified risks and the implementation of risk responses, as well as for identifying new risks and evaluating RM effectiveness.

Furthermore, the RMP must be a dynamic and continually updated document, as risks can evolve, and new threats may emerge as the project progresses. Ongoing maintenance and review of the RMP are essential to ensure the effectiveness of RM activities throughout the PLC (Miguel, 2019; Keshk et al., 2018).

2.3.3 Risk Identification

Risk identification is a crucial step in RM, requiring the active involvement of all project team members and the PjM. The primary goal is to identify and document potential risks that could affect the success of the project, providing a solid foundation for subsequent risk analysis and management throughout the PLC. When carried out effectively, risk identification enables proactive management of uncertainties, preventing them from escalating into significant problems (Rehacek, 2017).

Fostering a risk-oriented organizational culture is essential for the success of this process. This approach encourages team members to actively identify and address risks in their daily activities, strengthening the team's resilience and increasing the likelihood of project success (PMI, 2017).

As depicted in Figure 13, the risk identification process should incorporate three key perspectives: **past**, **present**, and **future**, ensuring a comprehensive evaluation of potential risks (PMI, 2017).

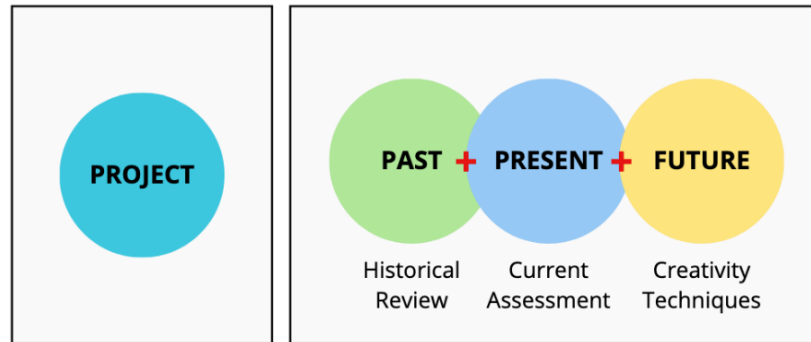


Figure 13: Risk Identification Perspectives (Adapted from PMI (2017))

Analyzing previous projects offers valuable insights by highlighting lessons learned and patterns that can inform current PM practices. Concurrently, studying the specific conditions of the current project helps identify unique risks and challenges that may arise. Furthermore, projecting into the future enables the anticipation of events or changes that could impact the project's progress (PMI, 2017; Miguel, 2019). Combining these approaches provides a more comprehensive view of potential risks (Rehacek, 2017).

According to Miguel (2019), several tools and techniques support risk identification, which can be applied across the different perspectives mentioned, including:

- i. **BRAINSTORMING SESSIONS:** A creative technique that involves group idea generation, allowing members to identify and discuss potential risks collaboratively.
- ii. **SWOT ANALYSIS:** This method examines internal and external factors that may influence the project, divided into four dimensions: Strengths, Weaknesses, Opportunities, and Threats, therefore broadening the range of factors to consider.
- iii. **CHECKLISTS:** Based on historical information, they provide a structured approach to risk identification, ensuring that all potential risks are considered.
- iv. **CAUSE AND EFFECT ANALYSIS:** Also known as the Ishikawa Diagram, this visual technique identifies the leading causes of risks, facilitating an understanding of their origins and potential impacts.

The final step in this process is documenting all identified risks in the project's **Risk List**. This dynamic document records all identified risks, including details such as nature, potential impact, probability of occurrence, and planned or implemented mitigation measures (Miguel, 2019). Updating this list is crucial

to keeping the team informed about emerging risks and ensuring effective corrective actions are taken (PMI, 2017).

2.3.4 Qualitative and Quantitative Risk Analysis

After identifying risks, it is crucial to conduct a comprehensive risk analysis and assessment. This process typically involves two primary methods: **qualitative** and **quantitative risk analysis**, each with unique advantages and limitations.

Qualitative risk analysis is a faster and more cost-effective approach that evaluates identified risks based on their **probability** of occurrence and potential **impact** (PMI, 2017). Generic scales, typically ranging from 1 to 5, are used to categorize the values for both probability and impact (Broto & Harahap, 2020). The **Risk Indicator** (RI) for each risk is determined by multiplying its probability by its impact, as illustrated in Figure 14. This calculation assists PjMs in determining the relative priority of each risk, guiding their decision-making.

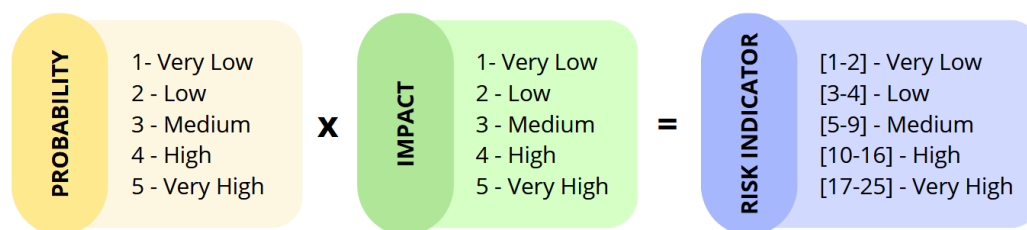


Figure 14: Risk Qualitative Assessment (Adapted from Broto & Harahap (2020))

The impact quantifies the potential consequences of a risk, which can range from very low to very high, as illustrated in Figure 14. The probability of occurrence, on the other hand, evaluates the likelihood of a risk event happening, typically expressed as a percentage or using a qualitative rating scale. By analyzing both impact and probability, the project's Risk List can be refined, allowing for the prioritization of risks that may require more detailed quantitative analysis. Risks with a higher RI, which indicates greater potential threats or opportunities, should receive greater attention and resources during RM planning and decision-making (Keshk et al., 2018). However, it is essential to recognize that the RI should not be the only factor guiding risk prioritization or the development of effective RM strategies.

To enhance RM processes, it is advisable to organize previously assessed risks intuitively (PMI, 2021). Visual tools, such as risk matrices, play a significant role in helping project teams comprehend the level of risk associated with each identified threat and prioritize their response strategies accordingly. For instance, the **Probability and Impact Risk Matrix** employs a two-dimensional grid to represent the

likelihood of a risk occurring on one axis and the severity of its impact on the other, as shown in Figure 15. The quadrant in which a risk is placed, typically indicated by colors ranging from green to red, reflects its overall significance.

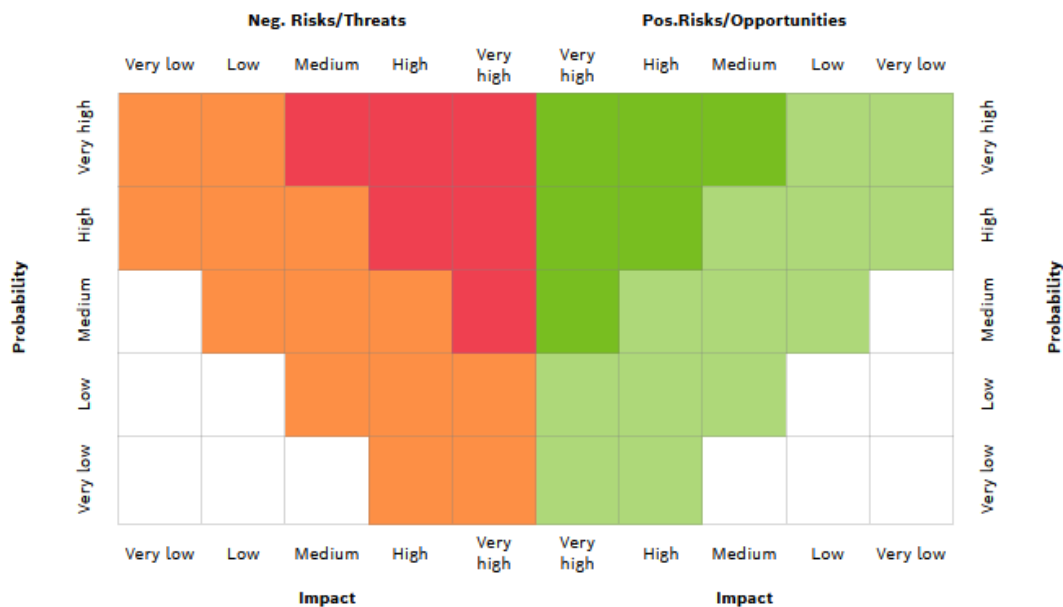


Figure 15: Probability and Impact Risk Matrix (Broto & Harahap, 2020)

After completing the qualitative assessment, the next step is to perform a quantitative risk analysis, which provides a numerical evaluation of identified risks to support prioritization and informed decision-making on mitigation actions (PMI, 2017). Common methods include Monte Carlo simulations, sensitivity analysis using tornado diagrams, decision trees, influence diagrams, and **Expected Monetary Value (EMV)** (PMI, 2017; Miguel, 2019).

The EMV is a widely used tool in quantitative RM. This method estimates the potential financial impact of a risk event by multiplying the Probability of the Risk Event by the Monetary Impact of the Risk Event. In this process, the probability of occurrence is expressed as a percentage, while the monetary impact represents the estimated financial cost or benefit, typically quantified in euros. By converting risks into monetary terms, EMV provides a clear basis for prioritizing mitigation actions according to their projected impact on the project's objectives (Hulett, 2020; PMI, 2021).

The applicability of these methods varies depending on the project's context and the need for analysis. Ideally, all risks in the Risk List should go through quantitative analysis to ensure more accurate RM decisions. However, analyzing every risk in complex projects can be challenging due to limited time and resources (Raz & Michael, 2001). Therefore, qualitative analysis plays a crucial role in prioritizing risks,

allowing quantitative efforts to focus on the most significant risks that could have the greatest impact on the project.

2.3.5 Planning and Implementing Risk Responses

After conducting qualitative and quantitative risk analyses, the next step is to plan risk responses, ensuring that risks are addressed effectively (PMI, 2017). These responses should consider each risk's priority, impact, and its contribution to the overall project risk profile, aiming to increase the likelihood of project success by proactively managing risks (Rehacek, 2017).

According to PMI (2017) these strategies, documented in the RMP, are designed to address both threats and opportunities. Strategies for **threats** (negative risks) include avoiding, transferring, mitigating, and accepting the risk. Strategies for **opportunities** (positive risks) may involve exploiting, sharing, enhancing, or accepting. Table 4 provides a summary of these approaches.

Table 4: Risk Response Strategies for Opportunities and Threats

	STRATEGY	DESCRIPTION
THREAT	Avoid	Eliminate the threat or protect the project from its impact.
	Transfer	Shift a threat to a third party to manage the risk and to bear the impact in case of occurrence.
	Mitigate	Reduce the probability of occurrence and/or the impact of a threat.
	Accept	Acknowledge the existence of a threat without taking action.
OPPORTUNITY	Exploit	Seek to capture the benefits of an opportunity by ensuring that it definitely happens.
	Share	Shift an opportunity to a third party so that it shares the benefits if the opportunity occurs.
	Enhance	Increase the probability of occurrence and/or the impact of an opportunity.
	Accept	Acknowledge the existence of an opportunity without taking action.

Once a risk response strategy has been selected, it is essential to develop an implementation plan. This plan should include the necessary actions, resource allocation, and a cost-benefit analysis to ensure efficient RM (PMI, 2017). Figure 16 illustrates the relationship between the costs of RM and the damage caused by risk occurrence.

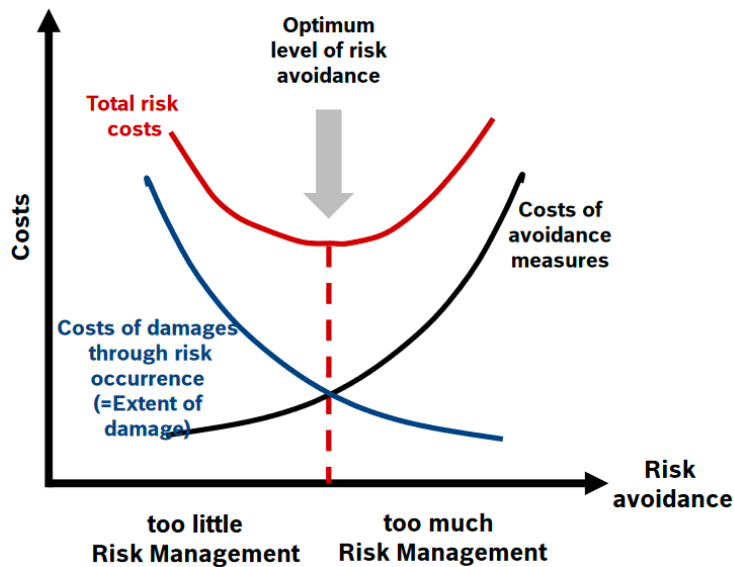


Figure 16: Optimizing Risk Management Level (Broto & Harahap, 2020)

The optimal level of risk avoidance is where total costs are minimized. With too little RM, damages are high, but prevention costs are low. On the other hand, excessive RM increases prevention costs without proportional benefits. The goal is to balance the cost of implementing responses with the potential impact of the risks.

Additionally, all risk responses must be recorded in the Risk List. If any actions impact the project's scope, schedule, cost, or quality, these changes should be reflected in the Project Management Plan. Implementing risk responses may result in **Lessons Learned**, documenting the challenges encountered and how they could have been avoided. This reflection not only contributes to the overall understanding of RM but also helps inform future projects (PMI, 2017).

2.3.6 Risk Monitoring

Risk monitoring is a critical component of the PLC to ensure that risk response measures remain effective. This ongoing process involves several key activities, such as tracking the implementation of the risk response plan, reassessing identified risks, analyzing new risks, and evaluating the overall effectiveness of RM practices (PMI, 2017).

To support effective monitoring, the Risk List must be continuously updated, incorporating new data and changes from both the project and its external environment. The frequency of these updates should be aligned with the project's complexity and risk level, ensuring risks are consistently re-evaluated and that the performance of response measures is documented thoroughly (PMI, 2021).

By maintaining up-to-date risk information, decision-makers are better equipped to understand the project's risk exposure and make informed adjustments. Keeping stakeholders informed about the evolving risk landscape and regularly assessing the effectiveness of response strategies enhances the project's resilience to potential threats (Shenhar, 2001; Mirboroon & Razavi, 2020).

2.4 Synopsis

The literature underscores the pivotal role of RM in PM, particularly in complex and innovative environments like NPD projects. RM provides a structured framework for identifying and addressing both risks and opportunities, which helps ensure that projects maintain quality while staying within timelines and budgets. QGs function as essential checkpoints, assessing whether each phase of a project meets predefined quality standards before progression. By validating progress at each stage, QGs help minimize deviations and promote consistent quality assurance.

The integration of RM and QGs can foster a synergistic relationship. While RM focuses on managing uncertainties, QGs emphasize maintaining high-quality standards throughout the PLC. This combination may enhance the achievement of project goals and ensure alignment with strategic quality objectives, thereby improving overall project outcomes.

Having presented the theoretical foundation that informs this research, the next step is to address the research question formulated for this dissertation:

In the context of New Product Development, do Risk Management practices contribute to the quality of the project?

This question will be explored through empirical research, which relies heavily on fieldwork and draws on multiple and diverse data sources. The next chapter delves into the case study within the automotive industry, providing a detailed context for the analysis.

3. CASE STUDY

This chapter will present the case study. The main objective is to provide an in-depth analysis of the situation identified, which is necessary to understand the research context. Section 3.1 begins with a presentation of the research context and methodology applied in this case study project. Subsequently, section 3.2 focuses on the analysis of the Bosch Group's general Project Management practices for New Product Development projects. Lastly, section 3.3 contextualizes a specific New Product Development project in which the researcher was involved.

3.1 Research Context and Methodology

This master's dissertation was developed within the Automotive Electronics (AE) sector, one of the nine divisions of the Mobility Solutions (BBM) business area, further detailed in Annex A. The project started with a proposal for a six-month curricular internship at Bosch Car Multimedia S.A., which offered the opportunity to develop a master's dissertation focused on the development of a new product specifically for a client.

As illustrated in Figure 17, the research was carried out within the Project Leads Team, which served as the core group for the study. This team was responsible for overseeing PM across three key areas: automotive clusters, head-up displays, and motorcycle clusters (two-wheelers).

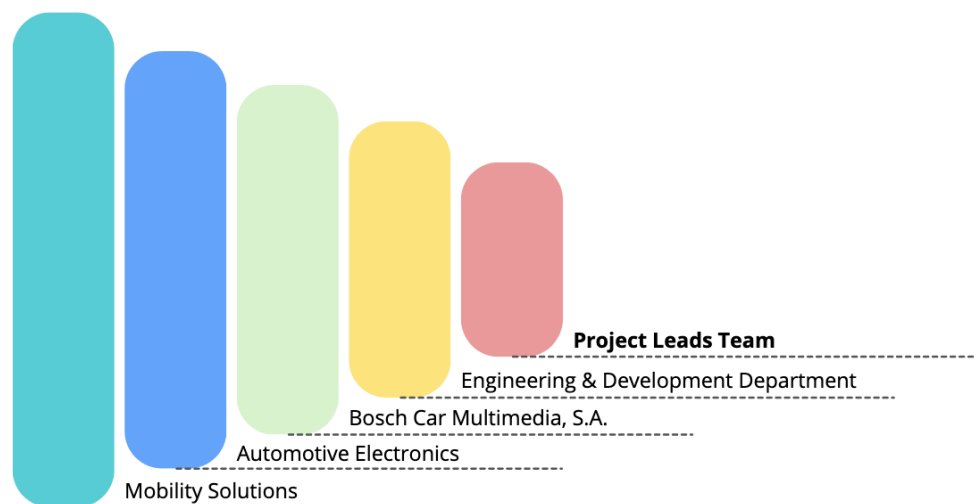


Figure 17: Study Context

A case study methodology was selected to enable an in-depth exploration of the NPD process within the AE sector. By focusing on a real-world context, this research aims to gather detailed insights into the practices, challenges, and outcomes associated with PM in this field. This approach is particularly

effective for examining situations within their real-life contexts and can complement other research methods. As a result, it allows the researcher to propose new practices based on comprehensive insights gained from the study.

The research employed an action research methodology, which allows for a reflective and iterative approach to investigation. According to Kemmis (1989), this method involved several concrete steps:

- i. **PLANNING:** Define the problem and create an action plan, exploring alternatives to improve the current situation.
- ii. **ACTION:** Implement the planned intervention, testing ideas in practice to observe improvements.
- iii. **OBSERVATION:** Collect data on the action's effects, documenting context, actions, and results through methods such as interviews and questionnaires.
- iv. **DOCUMENTATION:** Evaluate data and reflect on the intervention's effectiveness, identifying new insights and adjustments for future actions.

Multiple sources informed the diagnostic process, including direct observation, participation in meetings, training sessions, and workshops, as well as access to relevant documentation. Direct observation provided firsthand insights into team dynamics and operational workflows, while participation in meetings and workshops allowed for a deeper understanding of PM methodologies. Additionally, reviewing internal guidelines, project reports, and external resources such as the PMBOK® Guide offered important context and best practices relevant to the study.

This combination of direct involvement and documentary analysis enriched the diagnostic process, leading to a nuanced understanding of the complexities inherent in NPD within the AE sector.

3.2 NPD Project Management at Bosch

The importance of PM as a critical success factor within the organization is underscored by the international scope, size, and complexity of Bosch's projects. To standardize and outline the recommended elements of PM, Bosch has developed a Central Directive - the **Bosch Project Management Handbook** (Bosch, 2024a). This guide combines internal rules, specific processes, and methods unique to Bosch, while also incorporating best practices established in the PMBOK® Guide.

As illustrated in Figure 18, Bosch's PM practices are structured around five key areas: i) Processes & Methods; ii) Support; iii) Qualification & Career; iv) Assessment & Review; and v) Strategy & Leadership.

Each of these areas is extensively detailed in the Bosch Project Management Handbook, providing a comprehensive framework to support effective project execution across all levels of the organization.

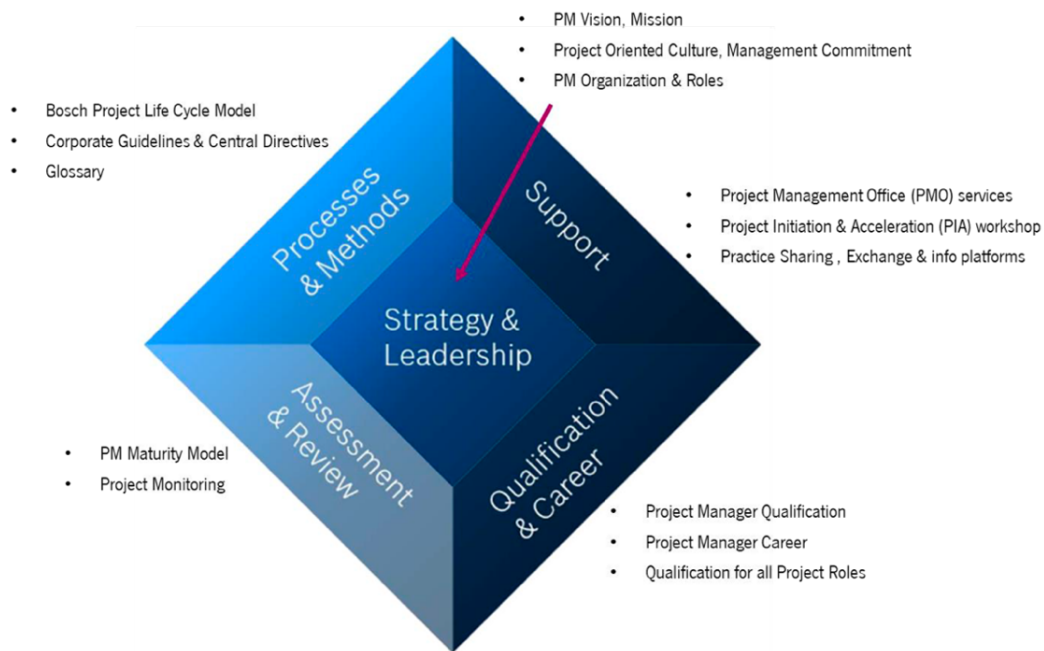


Figure 18: Project Management at Bosch (Bosch, 2024a)

Additionally, The Central Directive establishes a project categorization system that defines the qualifications required for professionals managing these initiatives. Bosch Braga has implemented a robust project categorization framework that is crucial for assessing the impact of each initiative on the operational unit and determining the necessary management requirements. This system is vital for the efficient allocation of resources, ensuring that each project receives the appropriate level of attention and expertise (Bosch, 2024b).

Bosch classifies project impact into at least three categories: **A**, **B**, and **C**, with Category A representing projects that have the most significant impact on the operational unit. Each operational unit has the flexibility to define additional categories beyond C, based on their specific needs. To determine a project's category, Bosch evaluates **six key criteria**, explained below, each rated on a scale from 1 to 5 points (Bosch, 2024a).

- i. **ECONOMIC IMPACT:** Measures the costs associated with the industrialization process.
- ii. **INNOVATION:** Assesses the level of innovation introduced by the project.
- iii. **SUBJECT MATTER EXPERTISE:** Refers to the specialized knowledge and technical skills required to execute the project.

- iv. **PROJECT STRUCTURE:** Quantifies the number of work packages necessary for the project's configuration.
- v. **INTERCULTURAL SET-UP:** Evaluate the cultural diversity of the project team.
- vi. **RISK EVALUATION:** Measures the level of risk associated with the project.

After individually evaluating each criterion, the sum of the scores indicates the project's category according to the following:

- i. **A CATEGORY:** more than 34 points.
- ii. **B CATEGORY:** 25 to 34 points.
- iii. **C CATEGORY:** 15 to 24 points.

A detailed matrix for project categorization can be found in Annex B, providing deeper insights into the criteria used in this classification process.

The PM landscape and associated procedures differ among Bosch's Business Areas, with each division implementing distinct teams and methodologies to address their specific needs. This is especially pronounced in the BBM Division (AE), which utilizes a unique PM approach tailored to the complexities and specialized demands of the automotive electronics sector. In this division, the PM landscape focuses on a customized framework designed to adapt to the changing requirements of the automotive industry (Bosch, 2024b). Figure 19 illustrates this landscape in relation to NPD projects.

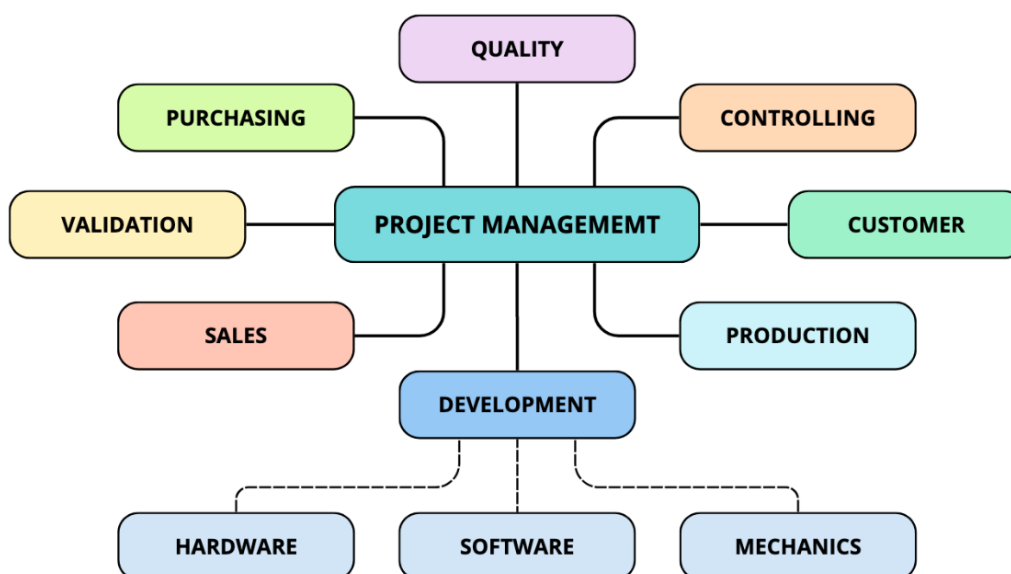


Figure 19: NPD PM Landscape in AE Unit (Adapted from Bosch (2024b))

It is important to note that, regardless of the project category or the specific PM landscape within each division, all NPD projects adhere to a common PLC, as explained in the following subsection. This ensures a standardized approach to PM across the organization, fostering consistency and enabling meaningful comparisons between different projects (Bosch, 2024a)

3.2.1 Bosch Project Life Cycle Model

The Bosch Project Management Handbook outlines the **Bosch Project Life Cycle Model (BPLM)**, which provides a general framework for PM within the company. This model is aligned with the PMI Project Management Process Model (PMI, 2017). As discussed earlier in subsection 2.1.4, the PMI model consists of five Process Groups. Bosch's BPLM adopts a similar structure, with phases corresponding to these Process Groups. Table 5 illustrates the alignment between the BPLM phases and the PMI Process Groups.

Table 5: BPLM Phases aligned with PMI Process Groups (Bosch, 2024a)

PROCESS GROUP	BPLM PHASE
Initiating	Request
Planning	Preparation
Execution/Monitoring & Control	Conception
Execution/Monitoring & Control	Implementation
Closing	Completion

The PLC at Bosch, as shown in Figure 20, follows the BPLM model and adopts a Stage-Gate approach with recommended subprocesses as phases. It outlines the full, global scope of a project, from the initial project request to its completion. To mark progress, each milestone is defined and approved by the Project Sponsor before moving on to the next phase. In this model, Lean Management principles can be applied throughout the project whenever necessary (Bosch, 2024a).

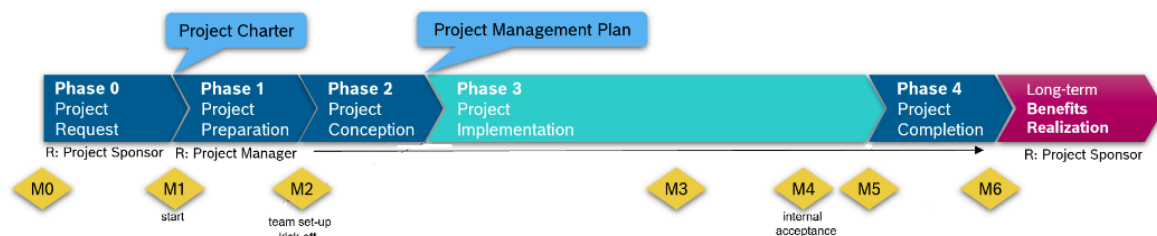


Figure 20: Bosch PLC Model (Bosch, 2024a)

Based on the Bosch Project Management Handbook (Bosch, 2024a), it is possible to explain each of the phases presented in Figure 20 in more detail. Annex C, specifically Figure 39, provides additional information on the processes, milestones, and activities present in each phase.

- i. **PROJECT REQUEST:** This phase begins at milestone M0 with formal approval to work on the project request. During this phase, the potential project must demonstrate its alignment with the project acceptance criteria, defined by the operational unit, and clarify how the organization will benefit from this potential new project. Milestone M1 marks the approval of the **Project Charter**, which includes the official appointment of the PjM.
- ii. **PROJECT PREPARATION:** The start of the second phase, corresponding to milestone M1, marks the beginning of project execution after the Project Charter has been approved. During the project preparation, the PjM assembles the project team to define the project scope and develop the **Project Management Plan**. The approval of milestone M2 officially establishes the full project team.
- iii. **PROJECT CONCEPTION:** In this phase, the **Project Management Plan** is finalized and approved, and this is linked to milestone M3.
- iv. **PROJECT IMPLEMENTATION:** This stage encompasses the primary work of the project and is the phase that generates the most value. It ends with internal acceptance at milestone M4 and external customer acceptance at milestone M5.
- v. **PROJECT COMPLETION:** The project completion activities conclude the project with the formal release of the team and the PjM at milestone M6.

After project closure, long-term benefits realization focuses on ensuring that the intended outcomes are achieved in the long term, such as product sales meeting expectations or the successful establishment of a new organizational setup.

Bosch employs two distinct standard procedures to initiate projects, depending on their origin. If a project is specifically requested by a client or if the company identifies a new and innovative business opportunity in the market, a tailored approach is adopted. For projects where a customer assigns the responsibility of developing a new product, Bosch initiates the Product Development Process (PDP), internally referred to as the Product Engineering Process (PEP). These initiatives, known as NPD projects, adhere to a PLC that is customized to meet the specific requirements, goals, and specifications of the product.

This tailored PLC ensures that NPD projects are aligned with their unique characteristics and objectives. The NPD process encompasses the specific stages, activities, and considerations necessary for the successful development of new products at Bosch, enabling the company to meet customer expectations and market demands efficiently.

For the purpose of this master's dissertation, the project under consideration involves the development of a product requested by a specific client, adhering closely to their specifications and requirements. Consequently, the milestones within this PLC focus on customer-oriented projects and are designated as Quality Gate Customer (QGC) milestones.

The primary goal of the PEP at Bosch is to efficiently develop new products, ensuring they are delivered on time, on specification, and on budget while maintaining outstanding quality (Bosch, 2024b). As illustrated in Figure 21, the PEP begins with a Project Request, supported by the milestones of the Sales Evaluations (from SE0 to SE4).

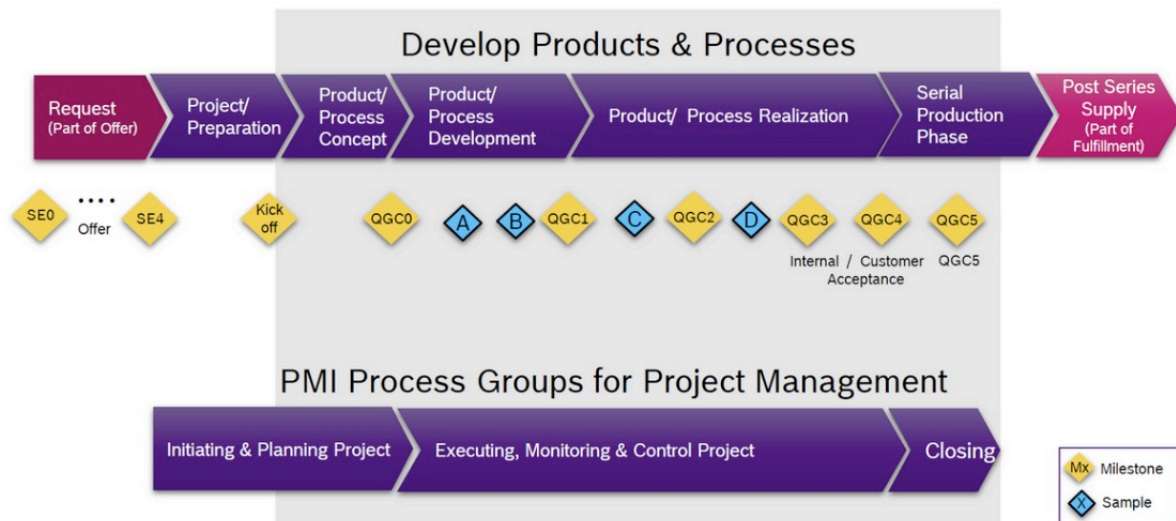


Figure 21: PEP Phase Model of NPD Projects at Bosch (Bosch, 2024a)

Once the request phase is completed, the PLC transitions into the Project Preparation phase, culminating in the official Project Kick-Off. Following this pivotal moment, the PLC advances through up to five evaluation stages, each integrated with QGC milestones.

For a detailed overview of the specific stages and decision-making processes involved in the QGC checkpoints, particularly as they relate to the sample phase, please refer to Figure 40. It is crucial to note that certain QGC milestones within the PEP may be skipped, depending on the project category. For Category A and B projects, all QGC milestones must be completed. However, for Category C projects, at least QGC0 and QGC4 are mandatory (Bosch, 2024b).

The project discussed in this dissertation has successfully passed the QGC0 milestone and is currently in the Product/Process Realization phase. For further insights into the activities associated with each phase of the QGC system, Figure 41 in Annex C provides a comprehensive overview of the detailed activities that occur at each QGC stage.

A vital aspect of the PEP, as illustrated in Figure 21, is the concept of sample phases. These phases play a crucial role in the timeline for launching a new product to market and are, therefore, significant in NPD projects. Sample phases are typically labeled **A**, **B**, **C**, or **D**, each corresponding to a distinct stage of product maturity and playing a specific role in the PLC. Table 6 presents a description of sample maturity in the PEP at Bosch, detailing the purpose and characteristics of each phase within the NPD framework.

Table 6: Description of Sample Maturity in the PEP at Bosch (Bosc, 2024b)

SAMPLE PHASE	PURPOSE	DESCRIPTION
A	Early prototype focused on functional validation. Used for basic testing, packaging studies, and customer feedback on initial functionality.	Manufactured with low maturity, using prototype methods, and often involving semi-finished parts and non-final materials. Modifications are common.
B	More advanced prototype, addressing technical requirements. Used for customer testing of functional scope, hardware, and system integration.	Built with high maturity, using trial tools and closer-to-final materials. Process design begins to take shape, but it's not fully industrialized yet.
C	Pre-production model that undergoes final validation by both Bosch and the customer. Used for design approval and preparation for series production.	Produced with fully functional maturity, using near-final materials and production tools. Series production processes are defined, and suppliers selected.
D	Final sample produced under series conditions. Used for final customer approval and production validation before mass production. Pilot series checks for manufacturing robustness.	Built with fully functional maturity (pilot production), using final production tools and processes. Software and hardware are aligned with series production requirements.

Table 6 emphasizes that each sample phase corresponds to a specific stage of testing and refinement, playing a pivotal role in the NPD process. These distinct phases are vital for ensuring that the final product aligns with the required specifications and is adequately prepared for commercialization at the Start of Production (SOP).

The product currently under consideration in this project is in the C sample production phase. For additional insights and a more comprehensive visual representation of the distinct processes associated with each sample phase within Bosch NPD framework, please refer to Figure 42 in Annex C.

3.2.2 Quality Gates Process at Bosch

QGs are integral to Bosch’s commitment to delivering products of the highest quality and reliability. They embody a proactive approach to PM, ensuring that risks are identified early and addressed effectively. This structured process enables continuous improvement, allowing projects to progress smoothly and confidently toward stable mass production (Bosch, 2024b).

The QG process is crucial for ensuring that projects stay on track and progress to the next phase by verifying the fulfillment of predefined measurement criteria. As illustrated in Figure 22, this effectiveness is achieved through a systematic, four-step process executed at each QG stage.

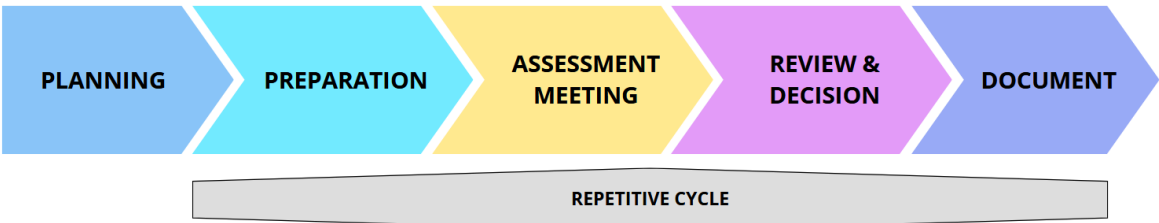


Figure 22: Quality Gate Cycle Process at Bosch (Adapted from Bosch (2024b))

Figure 22 highlights that the QG process begins with planning, which is the first step in the QG workflow and part of the overall project planning activities. This phase involves defining the QGs based on the project’s category. During this stage, participants from the relevant departments are nominated for the QG assessment, and the schedule for the QG reviews and assessments is established.

Next comes the preparation phase, where the agenda for the QG meeting is defined, including the topics to be discussed and the timeframes for each item. Necessary information and documents, such as questionnaires and technical documents, are prepared to ensure that the meeting is productive and focused.

The third step, assessment, involves the QG meeting itself, during which the project is evaluated against a predefined set of **measurement criteria**. These criteria are organized into various **process categories**, which correspond to different phases of the project and associated **QGC levels**. Below are the key categories and their respective roles in the process, as outlined by Bosch (2024b).

- i. **PROJECT MANAGEMENT:** Includes processes for Initiating, Planning, Executing, Monitoring & Controlling, and Closing the project.
- ii. **REQUIREMENTS MANAGEMENT:** Involves identifying and specifying all technical and non-technical project requirements.
- iii. **PRODUCT DEVELOPMENT:** Covers all activities that lead to defining the technical specifications of the product.
- iv. **PRODUCT VALIDATION:** This section focuses on the testing activities required to verify and validate that the product fulfills the specified requirements.
- v. **PROCESS DEVELOPMENT:** Encompasses the development of production processes that are aligned with the product specifications and production goals.
- vi. **PROCESS VALIDATION:** Involves testing and validating the production processes to ensure consistency and reliability in mass production.
- vii. **PRODUCT AND PROCESS APPROVAL:** Covers all activities necessary for the final approval and release of the product and process, ensuring readiness for the start of production.
- viii. **SUPPLY CHAIN:** This involves defining the logistics and delivery concepts, ensuring the efficient flow of materials and products through the supply chain.
- ix. **CHANGE MANAGEMENT:** Manages changes in products, processes, or requirements to maintain alignment with project goals.
- x. **RISK MANAGEMENT:** Focuses on identifying, assessing, and mitigating project risks to ensure smooth project execution.
- xi. **SERIES VALIDATION:** Encompasses the validation of both product and process in real-world production settings to confirm readiness for full-scale manufacturing.

These individual categories are composed of a specific number of measurement criteria, all of which are consolidated into a comprehensive **questionnaire**. Table 7 outlines the basic structure of this questionnaire, which outlines the number of criteria associated with each QGC milestone. This distribution

is aligned with the QGCs milestones presented in Figure 21, offering a clear framework for evaluating progress at each stage of the PDP.

Table 7: Overview of the QGCs Criteria Catalogue (Adapted from Bosch (2024b))

CATEGORIE	QGC0	QGC1	QGC2	QGC3	QGC4	QGC5	SUM
1. Project Management	14	9	12	9	12	8	64
2. Requirements Management	14	5	3	5	5	2	34
3. Product Development	8	8	6	7	5	1	35
4. Product Validation	5	3	3	4	4	2	21
5. Process Development	1	5	3	1	2	1	13
6. Process Validation	2	0	1	0	1	0	4
7. Product and Process Approval	2	0	3	5	4	0	14
8. Supply Chain	3	4	4	4	4	3	22
9. Change Management	1	1	1	1	0	1	5
10. Risk Management	3	2	2	2	2	1	12
11. Series Validation	0	2	3	1	3	3	12
TOTAL	53	39	41	39	42	22	235

The evaluation of each measurement criterion in the QGC criteria catalog follows a **traffic light system**. This system offers a clear visual representation of the status of each criterion, categorizing it into one of three ratings: **RED (R)**, **YELLOW (Y)**, or **GREEN (G)**. Additionally, Bosch includes a fourth category, **NOT APPLICABLE (N/A)**, to address criteria that do not require evaluation.

During the QG meeting, the team must reach a consensus on the rating for each measurement criterion. If consensus is not achieved, the most critical viewpoint is documented to ensure that all differing perspectives are acknowledged and considered. The lowest rating given to any of the measurement criteria then determines the overall project rating. This entire assessment process is supported by a specific internal software tool designed to facilitate the analysis and documentation of decisions.

A detailed explanation of each rating is provided in Table 8. For a comprehensive overview of the procedure used to evaluate the measurement criteria in the QG process, please refer to Figure 43.

Table 8: Quality Gates Rating of Criteria (Bosch, 2024b)

CRITERIA RATING	DESCRIPTION
● Red (R)	Indicates that the measurement criterion is not fulfilled . Although corrective measures have been agreed upon, there remains uncertainty about achieving the objectives. A management decision is necessary to determine the next steps.
● Yellow (Y)	Indicates that the measurement criterion is not fulfilled and that additional measures are necessary. Despite these issues, it is still anticipated that the objectives can be achieved with the implementation of these measures.
● Green (G)	Represents a successful outcome, where the measurement criterion is fulfilled . No additional measures are required, and the objectives are confidently expected to be achieved.
○ N/A	Denotes that the measurement criterion is not relevant .

At the conclusion of the QG assessment meeting, the results are presented to the Project Review Committee during the QG review meeting for evaluation and approval. If the project receives a green rating, it can progress to the next phase. For projects rated yellow, the committee examines the deviations and proposed corrective actions, assessing whether these measures will effectively bring the project back on track. Additional actions may be recommended before the project can proceed. In cases where a project receives a **red rating**, it is escalated to the divisional board. The board is responsible for deciding the project's course, which may involve halting the project, redefining its targets, repeating development stages, or accepting risks and allowing it to continue (Bosch, 2024b).

In addition to these decision-making processes, the QG activities involve comprehensive documentation efforts. This includes creating, maintaining, and archiving several key items, such as:

- i. **QG QUESTIONNAIRE:** Documents the assessment results for each measurement criterion.
- ii. **QG SUMMARY SHEET:** Provides a consolidated overview of the assessment results for each QG.
- iii. **QG REVIEW MINUTES:** Records detailed discussions, decisions, and actions taken during the review meeting.

Overall, in Bosch PM methodology, QGs are crucial for facilitating informed decision-making, managing risks, and ensuring smooth project progression. By consistently applying this process, Bosch maintains its high standards of excellence and innovation. As a result, Bosch consistently delivers products that

exceed customer expectations, setting new quality benchmarks in the automotive industry (Bosch, 2024b).

3.2.3 Risk Management at Bosch

At Bosch, the PJM is primarily responsible for managing project risks, focusing on identifying potential threats and formulating proactive responses. The effectiveness of RM is significantly enhanced through the active involvement of the entire project team, which broadens the scope of risk identification and fosters a collaborative environment. This collective approach ensures that risks are addressed from multiple angles, leading to informed decision-making and a stronger capacity to navigate uncertainties.

To facilitate effective RM, the PJM integrates discussions of the project's Risk List into regular team meetings, keeping all members informed about the project's status and existing risks. This practice enhances awareness and empowers the team to identify areas for improvement, make informed decisions, and adopt proactive measures. Including the Risk List in meeting agendas or organizing periodic risk workshops further strengthens these efforts.

During these meetings, the PJM and the project team update the status of mitigation efforts for each identified risk and assess any new risks that may arise. Vigilance is crucial, as the team must remain alert to potential risks from various sources and integrate these into the Risk List for timely evaluation. Newly identified risks should be thoroughly assessed and addressed with appropriate strategies based on predefined criteria.

In accordance with PMI guidelines, Bosch's RM process comprises several key components, including risk management planning, risk identification, risk analysis, risk response planning, and risk control throughout the PLC, described below according to Bosch (2024d). It is crucial to emphasize that these components should not be viewed as linear phases but are intended to be iterative and interconnected, as illustrated in Figure 12.

- i. PLAN RISK MANAGEMENT:** This step, conducted at the beginning of the PLC, encompasses the definition of how and when RM activities will be executed throughout the project. It involves developing the RMP, which must include the elements outlined in Table 3.
- ii. IDENTIFY RISK:** This process aims to uncover potential threats and opportunities that may impact the project. Conducted iteratively by the PJM and project team members, it involves determining the type, category, event, and effect of each risk. Bosch's standard risk categorization is outlined in the RBS, as shown in Figure 23.

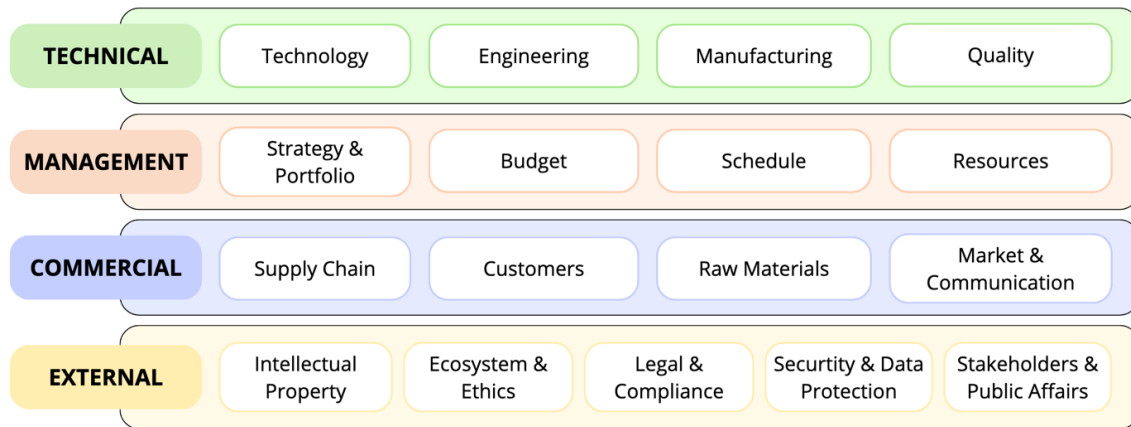


Figure 23: Risk Breakdown Structure at Bosch (Adapted from Bosch (2024b))

- iii. **PERFORM QUALITATIVE RISK ANALYSIS:** This step classifies and prioritizes risks by evaluating their probability and impact, as shown in Figure 14. Bosch Group uses a standardized global framework for qualitative risk analysis to maintain consistency and reduce uncertainty. However, the detailed nature of the criteria can make the process complex and time-consuming, introducing some subjectivity depending on the evaluator's perspective.
- iv. **PERFORM QUANTITATIVE RISK ANALYSIS:** Evaluate the quantitative impact of risks by assessing the costs associated with response strategies and the potential benefits of risk mitigation or avoidance. To streamline this process, calculating the EMV is recommended.
- v. **PLAN RISK TREATMENT:** Develop strategies through the establishment of measures aimed at increasing the likelihood of capturing opportunities while simultaneously decreasing the chances of threats, as illustrated in Table 4. These strategies should be evaluated based on their cost-effectiveness and overall impact, ensuring optimal RM, as demonstrated in Figure 16.
- vi. **MONITOR RISK:** Continuously review the Risk List with the risk team, subject matter experts, and stakeholders to ensure it remains current and relevant. This process includes updating the final status of risk characteristics and responses and documenting the outcomes as Lessons Learned for future reference.

RM practices at Bosch are effectively managed through the implementation of the **Super Open Points List** (SuperOPL), a proprietary tool that has transformed how the company addresses risks and tasks across its projects. This internally developed software is specifically designed for task management and risk assessment, meeting the diverse requirements of Bosch's project landscape.

Currently, around 70,000 users worldwide utilize the SuperOPL software, which serves approximately 400,000 Bosch employees. To enhance accessibility, SuperOPL is available in twelve languages, accommodating users globally. The logo of this software is displayed in Figure 24.



Figure 24: SuperOPL Logo (Bosch, 2024b)

SuperOPL supports the RM and task management at Bosch. The process begins with the identification of risks, documented in the software's Risk List. Following established RM protocols, as outlined in Annex E, this initial step involves classifying each risk as either a threat or an opportunity. Risks are then categorized according to the RBS, encompassing technical, management, commercial, or external aspects, as shown in Figure 23.

The software encourages users to formulate risks in the *"If...Then..."* format, which clarifies the distinction between the triggering event and its potential effects. These fields are mandatory, making it essential to complete this information when creating a new risk. Additionally, users can provide further details, including tags for domain categorization, potential impacts on other products or projects, root causes, risk indicators, risk thresholds, estimated occurrence dates, and other relevant notes.

The next phase in SuperOPL is the execution of qualitative and/or quantitative risk analyses. The software simplifies this process by providing dedicated fields for qualitative analysis. Risks are initially assessed based on their likelihood and impact using a scale ranging from very low to very high. Based on these inputs, the software automatically calculates the RI. After this evaluation, risks are positioned on the Probability-Impact Matrix for visualization.

To further enhance risk organization, users can apply tags, typically representing different domains, which facilitates easier filtering and categorization within the platform. After completing the qualitative assessment, users can proceed with quantitative analysis using the EMV method, entering the necessary data into the designated fields.

After creating a risk, users can establish measures categorized as decisions or tasks. These measures are automatically added to the software's **Open Points List**. When creating a measure, it's essential to specify the associated strategy type, as outlined in Table 4, along with the start date and a description. A responsible party must also be assigned to each measure. The software provides additional fields for

further details, such as priority level, due date, and associated costs if the user wishes to include them, as shown in Figure 49.

Measures can also be linked to the meeting where they originated, and any minutes or relevant documents from that meeting will be automatically attached to the corresponding measure. This feature ensures seamless tracking and integration of all key actions associated with RM. SuperOPL then organizes all these risks and their associated measures in the Risk List, as illustrated in the example in Figure 25.

No.	Author	Risk type	Category	Cause	Event	Effect	Prob.	Imp.	Eval.	Status
B9 (275096)		Negative	Technical							In work

ID	Strategy	Start date	Subject	Description	Responsible	Due date	Effective
7270611	Mitigate	08.07.24				31.08.24	
7163914	Mitigate	21.06.24				02.07.24	
7001605	Mitigate	02.04.24				31.05.24	
7001608	Mitigate	02.04.24				31.05.24	
7270619	Mitigate	08.07.24				31.08.24	
7001601	Mitigate	02.04.24				31.05.24	

Figure 25: SuperOPL RM Tool Overview (SuperOPL Software, 2024)

As demonstrated, each measure is assigned a responsible person and a due date, ensuring clear accountability for task ownership. Ideally, responsible individuals should consistently update these due dates to prevent any measures or risks from becoming overdue, thereby maintaining effective RM and ensuring smooth project progression. Additionally, users can view the associated tags for each measure, which facilitates better categorization and filtering, further enhancing the overall organization and tracking of risks and tasks within the software.

3.3 The Case Study Project

The case study focuses on a specific project of developing a new product, an advanced instrument cluster for 2-wheelers, designed exclusively for a specific client. At the beginning of this study, the product was about halfway through its PEP, as shown in Figure 26. Through close collaboration with the client, the PEP progresses in parallel with their requirements and feedback, ensuring that product development remains aligned with their needs and expectations. This approach allows continuous adaptation to the customer's evolving input, ensuring the final product is fully customized to their specifications.

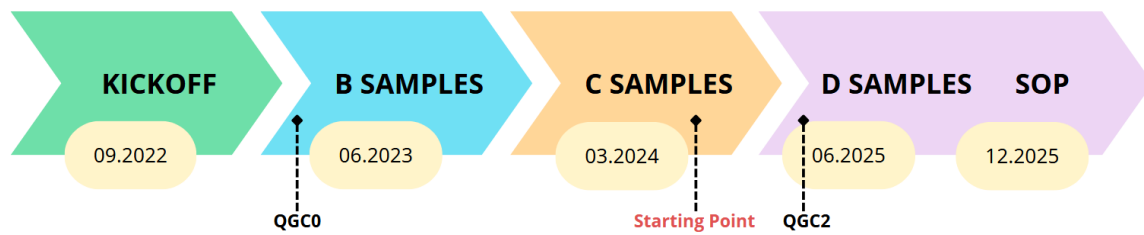


Figure 26: Timeline of the NPD project (Adapted from Bosch (2024b))

As illustrated in the Figure 26, the assessment of the current status of RM commenced shortly after the production of the C-sample prototypes, referred to as the “*Starting Point*”. At this stage, the project had entered the mid-development phase, and the team was actively preparing for the QGC2 milestone.

It is crucial to mention that the project did not undergo the QGC1 milestone. This decision was made because the project was classified as Category C, which follows the criteria outlined in section 3.2. This classification allows certain projects to bypass earlier milestones based on specific conditions, streamlining the development process.

In this project, the product development team is organized by department, as shown in Figure 27. Each department operates as an independent unit, adding layers of complexity to the overall project structure. Furthermore, the departments are geographically dispersed across multiple countries, as illustrated in Figure 27. This international distribution not only enriches the project’s approach with a wealth of diverse perspectives but also introduces specific challenges that must be adeptly managed to ensure the success of PM and RM strategies.

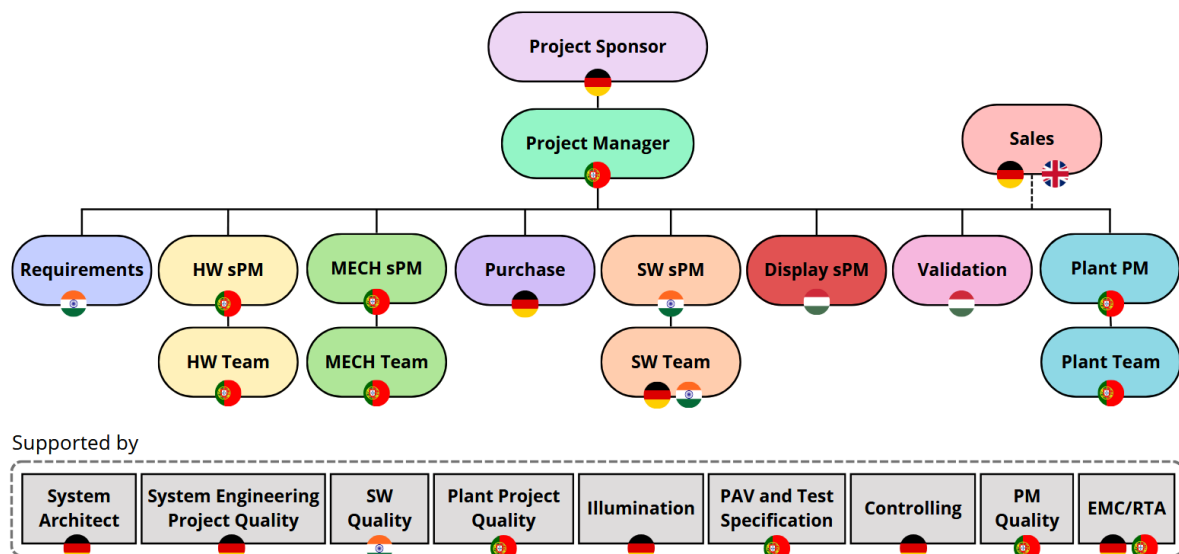


Figure 27: Organizational Chart - Project Team Roles (Adapted from Bosch (2024b))

Within this framework, the Sub-Project Managers, who oversee key development areas such as Hardware, Software, Mechanics, Plant, Display, Requirements, Purchasing, and Validation, maintain direct communication with the PjM. As key providers of data and expertise, these Sub-Project Managers serve as the primary sources of data and expertise for the PjM, enabling informed decision-making and ensuring efficient project oversight.

4. INITIAL SITUATION ANALYSIS

This chapter provides a comprehensive examination of the current RM practices within the project, with subsequent sections employing an action-research methodology that emphasizes an iterative cycle of planning, action, observation, and reflection.

Section 4.1 delves into the existing Risk Management Framework, focusing on its structure and processes. In section 4.2, a systematic analysis of the project's Risk List will be conducted, highlighting identified risks and the strategies implemented to mitigate them. Additionally, section 4.3 will review the QGC0 Assessment of the project, offering insights into performance metrics and the project's alignment with its defined objectives. Finally, section 4.4 will investigate the influence of Risk Management on Quality Gates through an evaluation of a set of projects, demonstrating the impact of effective Risk Management practices on project outcomes.

4.1 Current Risk Management Framework

Based on the current approach to RM within the team, team members tend to take a passive role in the identification, analysis, and control of risks. Although RM practices are integrated into routine processes, there is minimal proactive engagement from team members. Risk identification typically occurs reactively during meetings rather than through continuous monitoring and management. This reactive stance results in a less efficient and effective approach to managing risks throughout the PLC, limiting the team's ability to address risks promptly and comprehensively.

The teams conduct both monthly and weekly meetings to address a variety of important topics. However, the weekly **Team Meeting** is the singular opportunity for all members, particularly those in the Core Team previously presented, to come together. The meeting always follows a structured agenda, covering the three main topics: i) Schedule Update; ii) New Risks and/or Lesson Learned; and iii) Critical/Blocking Points to Prioritize.

When new risks or lessons learned arise during the meeting, the PjM promptly records them in the Meeting Minutes tool while sharing their screen with the team. Afterward, the PjM needs to ensure that these items are properly categorized and added to their appropriate sections in the platform to ensure accurate tracking and follow-up.

Once these updates are addressed, the PjM reviews each domain with its respective Sub-Project Manager, providing updates on the open points of each domain. However, due to time constraints and the volume

of topics often presented, there is sometimes insufficient time to properly address and discuss the second point. As a result, the Risk List may not be thoroughly reviewed or updated, leading to potential gaps in risk identification and assessment.

4.2 Risk List Analysis

To gain a thorough understanding of the initial state of the Risk List, data from the project was systematically gathered and analyzed. Figure 28 illustrates this starting point, providing a concise summary of key metrics, including the total number of identified risks, categorized by **threats** (negative risks) and **opportunities** (positive risks). In addition to the total count, the figure highlights the number of **overdue risks**, as well as those that **lack defined measures** and those **missing essential information**. Notably, for the risks missing essential information, criteria such as the absence of a risk event date were considered particularly significant, as critical fields such as category, type, event description, and effect are mandatory when creating risks in the software.

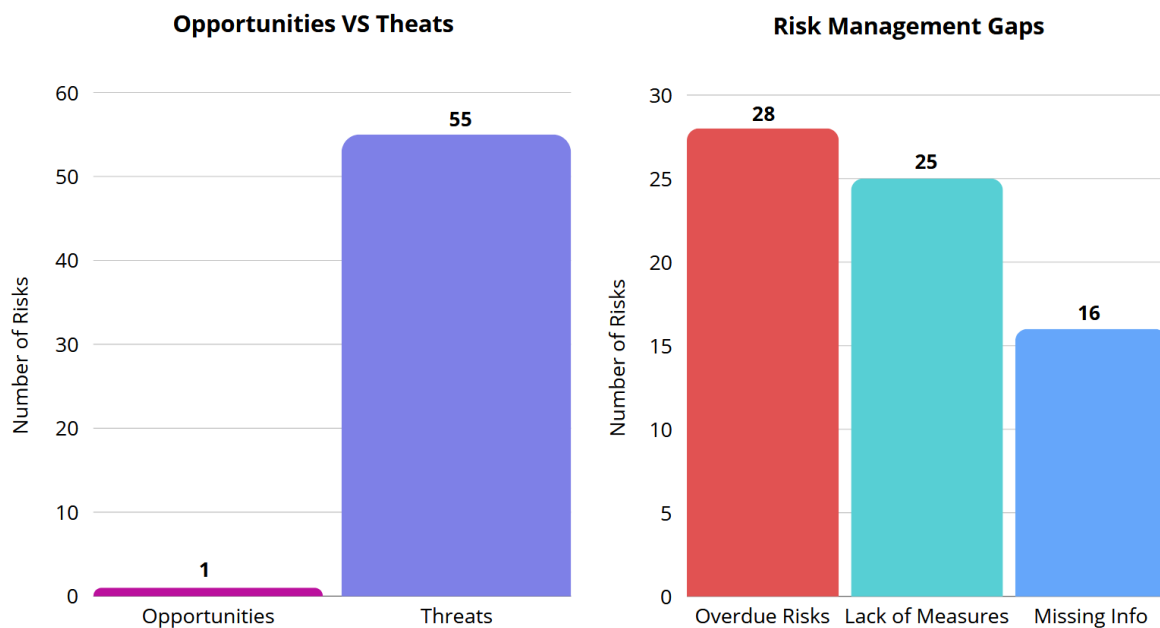


Figure 28: Initial Risk List Status

Figure 28 highlights the identification of **56 risks** categorized as *"in work + new"* in SuperOPL at the project's *"Starting Point"*, as described in Figure 26. Notably, **55 risks** (98.2%) are classified as threats, while only **1 risk** (1.8%) is identified as an opportunity. This striking imbalance indicates a significant underemphasis on potential positive outcomes, suggesting that the project team has primarily focused on mitigating negative risks while potentially overlooking opportunities that could add value to the project.

A pressing concern arises from the fact that **25 risks** (44.6%) lack defined measures, leaving the project exposed to unresolved threats with no strategic actions in place. Additionally, **28 risks** (50%) are flagged as overdue, meaning their expected event dates have already passed without any recorded updates or corrective actions. This points to a critical weakness in the ongoing risk monitoring process, reflecting a lack of proactive follow-up on high-priority risks. In addition, **16 risks** (28.5%) are missing key information such as event dates, descriptions, or impact assessments. These omissions significantly limit the team's ability to understand and respond to the risks effectively, ultimately undermining the overall effectiveness of the RM strategy.

Futhermore, the risk analysis process appears unstable, marked by significant inconsistencies in the team's risk assessments. Table 9 highlights the number of risks lacking essential information regarding both qualitative and quantitative analyses.

Table 9: Risks Assessment Status

QUANTITATIVE ASSESSMENT			
QUALITATIVE ASSESSMENT	Done	Not Done	TOTAL
Done	10 (17.9%)	34 (60.7%)	44 (78.6%)
Not Done	0	12 (21.4%)	12 (21.4%)
TOTAL	10 (17.9%)	46 (82.1%)	56 (100%)

As observed in Table 9, **46 risks** (82.1%) have not undergone quantitative analysis, despite **44 risks** (78.6%) containing qualitative information regarding probability and impact. This qualitative data is crucial for establishing a risk rating. However, the qualitative assessments have proven inconsistent, as team members often rely on their individual perspectives instead of following established criteria for risk evaluation. This reliance on personal viewpoints results in varying levels of risk identification and prioritization among the team.

The perception of risk across different cultures is a complex phenomenon that can significantly impact the risk analysis process. Cultural differences among team members may lead to varied interpretations of risk severity. For instance, some cultures are more risk-averse, viewing potential risks as more severe and threatening, while others adopt a more risk-tolerant stance, perceiving risks as less significant. These differing perspectives can result in inconsistent qualitative assessments, creating a lack of consensus and complicating the effective prioritization of risks.

Additionally, it was noted that **5 risks** (8.9%) have not been adequately articulated using *"If... Then..."* statements, despite the software promoting this practice. Consequently, the causal relationship between each risk and its potential impact has not been clearly defined, leading to ambiguous risk descriptions

that may not be easily understood by all team members. Clearly articulating risks is essential to ensure that everyone involved shares an understanding of the potential threats and opportunities, as well as their implications for the project.

Beyond collecting the total number of identified risks, the risks were categorized by domain, and the corresponding measures for each domain were reviewed. Table 10 shows the number of risks per domain, along with the associated measures. The domain in the last row encompasses topics that are general to the project, typically associated with PM, and are not specific to any particular domain.

Table 10: Identified Risks and Measures by Domain

DOMAIN	Nº of Risks	Created by the PjM	Nº of Measures	Created by the PjM
Hardware	18	9 (50%)	12	6 (50%)
Software	17	6 (35.3%)	13	8 (61.5%)
Mechanics	9	5 (55%)	6	6 (100%)
Plant	7	5 (71.4%)	5	5 (100%)
Display	3	1 (33%)	1	1 (100%)
Purchase	3	3 (100%)	2	2 (100%)
Validation	0	0	0	0
Requirements	1	1 (100%)	0	0
Other	11	8 (72.7%)	7	7 (100%)

As illustrated in Table 10, while the Validation domain lacks any identified risks or corresponding measures, most of the other domains with identified risks show that a significant portion of those risks and measures were created by the PjM.

Notably, the Hardware and Software domains stand out as the most active and proactive in terms of RM. A substantial number of risks and corresponding measures in these domains were identified independently of the PjM. This autonomy demonstrates the commitment of subject matter experts to proactively manage risks within their areas of responsibility. Their capability to identify and address risks independently reflects a strong focus on RM, fostering a culture of accountability and collaboration within the teams.

In the end, this embrace of risk demonstrates that the RM in these domains can be considered at a very high level. It underscores the benefit of acting wisely in addressing potential, already present barriers, which can only contribute to the achievement of the project will complete. Besides other factors, they are the most active in RM playing a key role in the project's success and serving as a positive example for the other domains.

4.3 Quality Gate Customer Assessment

Concurrently with the compilation of the project's Risk List, the QGC0 assessment was conducted, as illustrated in Figure 26, and meticulously documented. This assessment represents a critical milestone within Bosch's PEP and is initiated at the project's outset, providing a solid foundation for successful execution.

During this initial phase, key project objectives and organizational structures are clearly defined, enabling stakeholders to align their goals and responsibilities effectively. Specific requirements are articulated, and verification criteria are established and agreed upon, ensuring that all involved parties have a shared understanding of what constitutes project success.

Table 11 presents a comprehensive overview of the QGC0 assessment results, categorized according to the categories detailed earlier. Each category is evaluated based on predefined measurement criteria, with color-coded ratings indicating performance levels, as explained in Table 8.

Table 11: QGC0 Assessment Overview

CATEGORIE	● RED	● YELLOW	● GREEN	● N/A	RATING
1. Project Management	0	4	8	2	Yellow
2. Requirements Management	0	6	5	2	Yellow
3. Product Development	0	2	2	1	Yellow
4. Product Validation	0	2	2	1	Yellow
5. Process Development	0	1	0	0	Yellow
6. Process Validation	-	-	-	-	-
7. Product and Process Approval	0	0	1	0	Green
8. Supply Chain	0	3	0	0	Yellow
9. Change Management	0	0	1	0	Green
10. Risk Management	0	0	3	0	Green
11. Series Validation	-	-	-	-	-
OVERALL RATING					Yellow

As observed, some categories exhibit measurement criteria rated as yellow, resulting in an overall yellow rating for those categories, as the overall category rating is determined by the lowest rating assigned to any of the measurement criteria. This indicates that the measurement criteria are not fulfilled, necessitating additional measures. Despite these shortcomings, it is anticipated that the objectives can still be achieved with the implementation of the necessary corrective actions.

Conversely, certain categories have measurement criteria only rated as green, leading to an overall green rating for those areas. This represents a successful outcome where the measurement criteria are met, indicating that no additional measures are required, and the objectives are confidently expected to be achieved.

Overall, the yellow rating signifies that while the project is making progress, several critical areas require immediate attention to ensure that objectives are met effectively. Addressing these issues promptly will be essential to reduce potential risks and avoid any negative impact on the project timeline. By focusing on the identified shortcomings and implementing corrective actions, the team can enhance performance, encourage collaboration among stakeholders, and sustain progress toward achieving project goals.

4.4 Study of Risk Management Influence on Quality Gates

To investigate the influence of RM practices on project quality, 15 NPD projects were analyzed. The ratings of QGCs were used as indicators of project quality. The primary focus of this analysis was to evaluate the RM measurement criteria associated with each QGC rating and examine how these ratings influence the overall quality of the NPD projects.

This study aims to deepen the understanding of how effective RM practices correlate with improved project quality within the context of NPD. By systematically exploring the relationship between RM and project quality, the findings will offer valuable insights for organizations seeking to optimize their RM strategies and enhance the quality of their NPD initiatives. Ultimately, this research aims to demonstrate the critical role that robust RM plays in ensuring successful project outcomes.

4.4.1 Sample Description

To conduct the analysis, the dataset from the selected NPD projects was meticulously examined. Detailed information was collected regarding the ratings for each of the six QGCs (from QGC0 to QGC5), along with the corresponding RM measurement criteria linked to each QGC. In total, 12 variables were analyzed, as summarized in Table 12, which encompasses both the QGC ratings and the associated RM measurement criteria ratings across all six stages of the QGC process.

Table 12: Summary of Variables Analyzed

VARIABLE	TYPE	DESCRIPTION
QGC Rating	Nominal	6 QGCs ratings (from QGC0 to QGC5)
RM Rating	Nominal	6 RM ratings (from QGC0 to QGC5)

The detailed data collected for each project is presented in Appendix 1, which includes a comprehensive table summarizing both the QGC ratings and the corresponding RM ratings for each stage of the QGC process. It is important to note that for Project 12, assessments for QGC2 and QGC3 were not conducted, resulting in only 14 cases available for analysis regarding these specific QGCs and their associated RM measurement criteria.

Figure 29 provides a graphical representation of the distribution of ratings for both QGCs and RM across the PLC, illustrating the results for the 15 completed NPD projects. This visualization enhances our understanding of the relationships and distributions of ratings for RM and QGCs, offering insights into how these factors interact within the context of project performance.

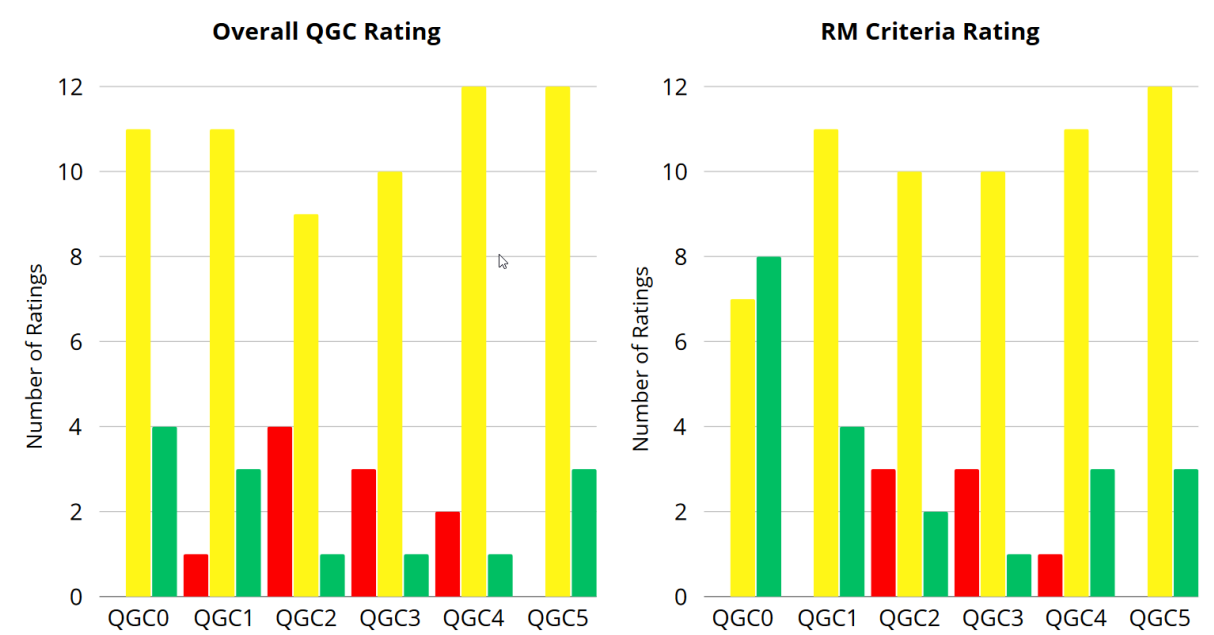


Figure 29: QGCs and RM Ratings per QGC

In Figure 29, each bar in the charts reflects the number of ratings classified under three levels of fulfillment: **GREEN**, **YELLOW**, and **RED**, corresponding to the criteria outlined in Table 8. This color-coding system indicates varying maturity levels of the QGCs and the effectiveness of RM practices within the evaluated projects.

To facilitate a series of statistical tests, the color ratings were transformed into numerical indicators, with each color corresponding to a specific value:

- i. ● **RED (0)**
- ii. ● **YELLOW (2)**
- iii. ● **GREEN (4)**

In this study, indicators were calculated for both the overall QGC ratings and the RM ratings. The methodology for calculating these indicators involved converting qualitative ratings, represented by colors, into quantitative values. This transformation facilitates more straightforward statistical analysis and aids in investigating potential correlations between RM practices and QGC outcomes.

For each project, the overall QGC rating indicator was determined by summing the products of the number of criteria associated with each color rating and its corresponding numerical value. Similarly, the RM ratings were calculated using the same approach, whereby the number of measurement criteria for each color in the RM context was multiplied by its corresponding value, resulting in a comprehensive assessment of RM performance.

The average of these indicators, calculated for each QGC and aggregated across projects, is presented in Table 13. In this table, higher indicator values denote superior performance, indicating stronger adherence to quality and RM standards.

Table 13: Average Indicator for QGCs and RM Ratings per QGC

QGC	QGC INDICATOR	RM INDICATOR
QGC0	3.0	3.2
QGC1	2.8	2.9
QGC2	2.1	2.3
QGC3	2.0	1.7
QGC4	2.3	2.5
QGC5	2.8	1.9
AVERAGE	2.5	2.7

For the subsequent statistical analyses, global indicators were considered, calculated similarly for both QGCs and RM. This involved aggregating all ratings from QGC0 to QGC5 to provide a comprehensive view of performance across the entire set of criteria.

4.4.2 ANOVA

To assess the influence of project categories (A, B, and C) on the indicators for QGC and RM an Analysis of Variance (ANOVA) was conducted. This statistical method enables the comparison of mean values across different groups to determine whether any significant differences exist.

The dataset includes multiple projects categorized as A, B, or C, with corresponding ratings for various QGCs (QGC0 to QGC5) and RM. Each project has been assigned an overall indicator for both QGC and

RM, which reflects performance as determined by a numerical scoring system (GREEN = 4, YELLOW = 2, RED = 0).

In this analysis, the project category serves as the independent variable, while the dependent variables are the Indicator QGC and Indicator RM. The null hypothesis (H_0) suggests that there are no significant differences in the mean indicator scores among the three project categories, while the alternative hypothesis (H_1) suggests that at least one category has a different mean score.

The results of the ANOVA, as shown in Table 14, indicate a significance value (Sig) lower than the alpha levels of 0.001 and 0.05, respectively. This suggests that the mean scores for both the QGC and RM indicators across the three project categories are statistically significant. Therefore, it can be concluded that meaningful differences exist in the average scores among the groups, which necessitates further investigation into the specific categories contributing to these differences.

Table 14: ANOVA Results for QGC and RM Indicators (SPSS Software, 2024)

		ANOVA				
		Sum of Squares	df	Mean Square	F	Sig.
Indicator RM	Between Groups	4.194	2	2.097	8.180	.006
	Within Groups	3.076	12	.256		
	Total	7.269	14			
Indicator QGC	Between Groups	1.099	2	.549	3.589	.060
	Within Groups	1.837	12	.153		
	Total	2.936	14			

Given that the ANOVA results indicated significant differences, post-hoc tests were performed to further investigate where these differences lie among the project categories. This post-hoc analysis provides insights into the pairwise comparisons of the scores between the project categories, allowing for a clearer understanding of how category membership influences both QGC and RM scores.

As shown in Table 15, for the **RM indicator**, two distinct groups were identified: **Group A** (projects categorized as A) and **Group B/C** (projects categorized as B and C). The post hoc analysis revealed statistical significance at the 1% level for the comparison between categories A and C, and at the 5% level between categories A and B. These findings, reflected in the table, underscore notable variations in RM performance across the analyzed project categories.

Table 15: Post Hoc Analysis Results for RM Indicator (SPSS Software, 2024)

Indicator RM			
Tukey HSD ^{a,b}			
Project Category	N	Subset for alpha = 0.05	
		1	2
A	3	1.633	
B	7		2.843
C	5		3.060
Sig.		1.000	.802
Means for groups in homogeneous subsets are displayed.			

- i. **Group A:** Projects in this group exhibited lower average scores in the Indicator RM, indicating that projects in this category may struggle with their RM practices. This outcome suggests that these projects could be experiencing challenges such as insufficient risk assessment processes, limited stakeholder engagement, or inadequate strategies for mitigating identified risks. The lower performance in RM signifies a need for improvement in how these projects identify and address potential risks, which is critical for ensuring overall project success.
- ii. **Group B and C:** Projects in this group displayed higher average scores in the Indicator RM. This suggests that these projects are likely benefiting from more effective RM practices. The higher scores in RM for these categories may imply more robust planning, better resource allocation, and enhanced collaboration among stakeholders. The effectiveness of RM in these groups indicates a proactive approach to identifying and mitigating risks, which is essential for improving project outcomes.

In contrast, the analysis of the **Indicator QGC** revealed a singular group with consistent performance levels across the board. This uniformity indicates that all project categories, irrespective of their classifications, share a commonality in their QGC ratings. Such a finding may suggest that the criteria for assessing QGC are consistently applied or that there is a baseline level of quality maintained across all project categories.

The implications of these findings are significant. While the Indicator RM highlights the need for targeted improvements in RM, particularly for Group A, the consistent performance in the QGC ratings suggests that the foundational quality standards are being upheld across all categories.

Overall, these insights emphasize the necessity for tailored strategies in RM practices, especially for the lower-performing Group A. By addressing the specific challenges faced by this group, organizations can

enhance their RM frameworks, which, in turn, may lead to improved quality outcomes reflected in the QGC scores.

4.4.3 Linear Regression

Following the ANOVA analysis, a correlation analysis was conducted to further explore the relationship between the RM Indicator and the QGC Indicator. A hypothesis test was performed, where the null hypothesis (H_0) suggests that there is no significant correlation between the two indicators, implying that the variables are independent. Conversely, the alternative hypothesis (H_1) suggests that there is a significant correlation between the indicators, indicating that the variables are not independent.

The results of the Pearson correlation analysis, presented in Table 16, indicate that the correlation coefficient between the RM Indicator and the QGC Indicator is 0.884, with a significance value (Sig) lower than the alpha level of 0.001. This suggests a strong and statistically significant positive correlation between the two indicators. Given that the significance value (Sig) is less than 0.001, the null hypothesis, which asserts the independence of the variables, can be rejected.

The significant correlation of 88.4% implies that as RM Indicator improve, there is a tendency for the QGC Indicator to also show higher levels. This indicates that the effective implementation of RM strategies is associated with improved overall project quality performance.

Table 16: Correlation Analysis Results between RM and QGC Indicator (SPSS Software, 2024)

Correlations			
		Indicator QGC	Indicator RM
Indicator QGC	Pearson Correlation	1	.884**
	Sig. (2-tailed)		<.001
	N	15	15
Indicator RM	Pearson Correlation	.884**	1
	Sig. (2-tailed)	<.001	
	N	15	15

** . Correlation is significant at the 0.01 level (2-tailed).

Building on this correlation analysis, a linear regression analysis was conducted to investigate the potential cause-and-effect relationship between the RM Indicator and the QGC Indicator. Specifically, the aim was to quantify how changes in RM practices (represented by the RM Indicator) influence the overall quality of projects (represented by the QGC Indicator). In this regression model, Indicator QGC was treated as the dependent variable, while Indicator RM was the independent variable. The purpose was to

determine the predictive capacity of RM practices on project quality. The results of this regression analysis are summarized in Table 17.

Table 17: Linear Regression Analysis Results (SPSS Software, 2024)

		Coefficients ^a				
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.037	.227		4.566	<.001
	Indicator RM	.562	.082	.884	6.834	<.001

a. Dependent Variable: Indicator QGC

The results of the initial linear regression analysis indicate that the unstandardized coefficient for the RM Indicator is 0.562. This suggests that for every one-point increase in the RM rating, there is an expected increase of approximately 0.562 points in the project quality rating. Additionally, the standardized coefficient of 0.884 demonstrates a strong relationship between these two variables, indicating that changes in RM ratings significantly impact QGC ratings. The significance values (Sig) for both the constant and the RM Indicator further confirm that these relationships are statistically significant at the 1% significance level.

Additionally, the analysis revealed an R^2 value of 0.782, meaning that 78.2% of the variability in QGC ratings can be explained by changes in RM ratings. This high proportion underscores the effectiveness of RM practices in influencing project outcomes, highlighting that improvements in RM strategies are strongly correlated with better quality ratings in projects.

To further investigate the determinants of project quality outcomes, a subsequent regression analysis was conducted to examine the potential explanatory power of project categories (A, B, or C). Specifically, this analysis sought to determine whether project categories contribute significantly to explaining variations in project outcomes, as measured by the QGC Indicator, beyond the influence of RM practices.

For this analysis, a dummy variable was created to represent project categories based on the post hoc analysis from the ANOVA, combining Categories B and C into a single group, which was assigned a value of 1, while Category A was designated as the reference group, assigned a value of 0. This dummy variable was included alongside the RM Indicator to assess whether project categories provide additional explanatory power in predicting QGC ratings, independent of RM practices. The QGC Indicator served as the dependent variable, while the RM Indicator and the dummy variable for project categories were the independent variables.

The regression model demonstrates strong explanatory power, with an adjusted R^2 value of 0.753. This indicates that 75.3% of the variation in QGC ratings can be explained by the RM Indicator and the project category dummy variable. The overall results of the regression analysis, including coefficients, standardized coefficients, and significance levels, are summarized in Table 18.

Table 18: Linear Regression Analysis Results - Dummy Variable (SPSS Software, 2024)

Coefficients ^a					
Model		Unstandardized Coefficients		Standardized Coefficients	Sig.
		B	Std. Error	Beta	
1	(Constant)	.994	.246		4.044
	Indicator RM	.616	.127	.970	4.850
	Category_Dummy	-.126	.221	-.114	-.570

a. Dependent Variable: Indicator QGC

The results of the linear regression analysis indicate that the unstandardized coefficient for the RM Indicator is 0.616. This suggests that for every one-point increase in the RM rating, there is an expected increase of approximately 0.616 points in the project quality rating. Furthermore, the standardized coefficient of 0.970 highlights the strength of the relationship between RM ratings and QGC ratings. The significance values (Sig) associated with both the constant and the RM Indicator are highly significant at a 1% significance level, confirming that the observed relationships are statistically meaningful.

In contrast, the project category dummy variable does not significantly contribute to the model, as shown in Table 18. The lack of statistical significance, with a Sig value of 0.579, indicates that the type of project (Categories A, B, or C) does not meaningfully influence the QGC ratings beyond the explanatory power provided by RM practices.

The findings highlight the dominant role of RM practices in determining project quality outcomes. The RM Indicator demonstrates a strong and statistically significant relationship with QGC ratings, underscoring that effective RM is a key factor in project success. In contrast, the project category dummy variable did not provide additional explanatory power to the model, suggesting that the type of project (A, B, or C) does not significantly affect project quality beyond the influence of RM practices.

These results emphasize the importance of prioritizing RM strategies to enhance project quality. The analysis indicates that the improvement of project outcomes is primarily driven by how risks are managed, rather than by the project category. As such, organizations should focus on refining their RM practices to ensure high-quality results. From a practical standpoint, the findings suggest that treating RM as a core

component of project strategy is crucial. Strengthening RM frameworks will likely lead to more successful projects, regardless of category, and contribute to greater stakeholder satisfaction.

4.5 Results Discussion

The preliminary analysis indicates that RM practices have a substantial impact on project quality. The assessment conducted in this chapter identified several common factors contributing to inefficiencies in RM practices, which negatively affect project outcomes. Understanding these factors is essential, as they provide valuable insights into improving RM processes and, consequently, enhancing overall project quality.

To systematically identify and analyze the root causes of inefficiencies in RM practices, an Ishikawa diagram was developed, as shown in Figure 30. This diagram offers a structured representation of the underlying issues, categorizing them across multiple dimensions. By visually mapping these factors, stakeholders can better understand their interrelationships and dependencies, thereby identifying critical areas for targeted intervention and improvement.

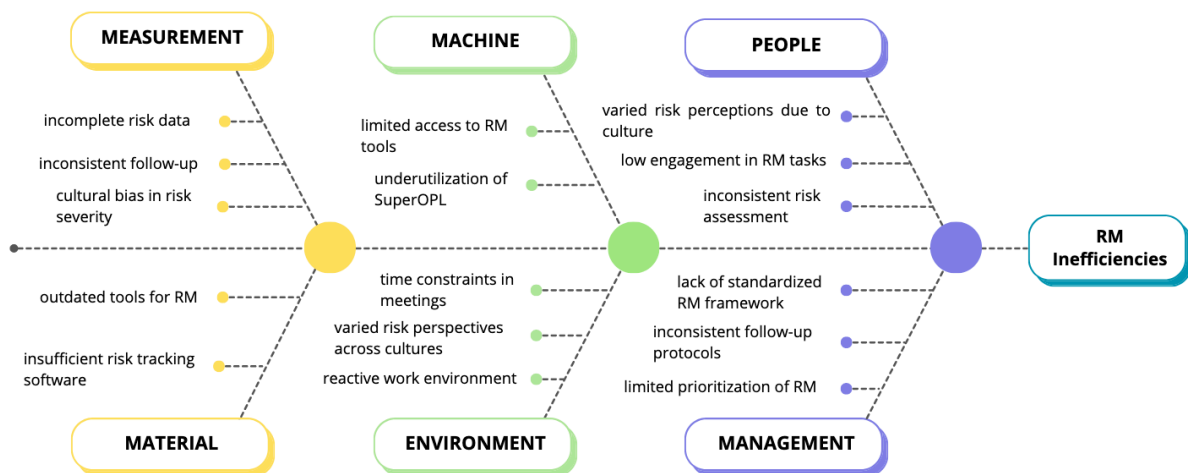


Figure 30: Ishikawa Diagram Illustrating Root Causes of RM Inefficiencies

Identifying the root causes of inefficiencies requires a thorough discussion and the development of strategies and corrective actions aimed at enhancing the quality and efficiency of project execution. Aligning these strategies with established quality objectives promotes a culture of continuous improvement, ensuring that all aspects of PM are directed toward achieving optimal outcomes. The insights gained from the Ishikawa diagram serve as a foundation for formulating targeted interventions to address the identified inefficiencies. By implementing these interventions, organizations can improve RM practices, thereby enhancing overall project performance and ensuring alignment with strategic goals.

5. PROPOSALS FOR IMPROVEMENTS

As discussed in the previous chapter, RM practices play a crucial role in determining the quality of project outcomes. Several critical factors contributing to inefficiencies in these practices have been identified. This chapter focuses on presenting targeted proposals designed to address these issues and enhance RM practices. The proposed strategies aim to streamline RM processes and significantly improve project quality.

Section 5.1 introduces improvements for each component of the Risk Management Plan, aiming to establish a more comprehensive and proactive approach to managing risks throughout the project. To promote awareness of potential risks and ensure the consistent application of standardized RM processes, section 5.2 explains the Risks Workshop. In section 5.3, several improvement proposals for the components of the RMP are elaborated further. Section 5.4 offers suggestions for managing tasks derived from the QGC questionnaire, ensuring their effective execution. Finally, section 5.5 provides additional recommendations to optimize the functionality and capabilities of the SuperOPL, enhancing its contribution to RM and project quality.

5.1 Risk Management Framework

Planning for RM constitutes a pivotal phase within the PM process, as it establishes the framework for executing RM activities throughout the PLC. A central deliverable of this phase is the RMP, which specifies the processes, tools, and techniques employed to manage risks across the project lifecycle. The effectiveness of the RMP is intrinsically linked to the refinement of its individual components, as discussed in section 2.3.2.

To optimize the RMP, it is essential to enhance each of these components, fostering a more comprehensive and proactive approach to RM. Such refinement strengthens the RM process, rendering it more resilient and adaptable to the evolving demands of the project environment. Moreover, the continuous improvement of the RMP ensures that RM practices are implemented systematically while remaining flexible enough to address emerging challenges effectively throughout the PLC. This dynamic approach not only mitigates risks but also supports the identification and utilization of opportunities to improve project outcomes.

- i. **METHODOLOGY:** For the project in question, the software used for RM is SuperOPL, which has proven to be the most effective tool for tracking and managing risks. Given its efficiency in risk

documentation, analysis, and follow-up, continuing to use SuperOPL is considered best practice for ensuring that all RM activities are carried out consistently and accurately across the project.

- ii. **RISK CATEGORIES:** To categorize project risks effectively, the project team uses Bosch's RBS, as presented in Figure 23. This RBS framework, aligned with Bosch's best practices, provides a structured approach to risk identification and management.

A new practice in this project is the use of tags within the software to categorize and navigate risks by domain. As shown in Table 19, these tags allow for efficient sorting and searching of risks, with each tag representing a specific domain or area of expertise. This system enables the project team to quickly identify and address risks in a targeted manner.

Table 19: Tags in SuperOPL for Risk Categorization

TAG	DESCRIPTION
PLANT	Industrialization Plant
PM	Project Management
HW	Hardware
SW	Software
MECH	Mechanics
DISPLAY	Display
PUR	Purchase
VAL	Validation
REQ	Requirements
TOP 5	Top 5 Highest-Rated Risks

As shown in Table 19, the tags are organized by project domain, allowing each risk to be associated with one or more relevant areas. This structure facilitates cross-domain collaboration whenever a risk affects multiple fields. The tags are specifically designed to capture key risk-related information, including high-risk ratings and the domains impacted by these risks. Additionally, the "TOP 5" tag identifies the most critical risks at any given moment, ensuring that these high-priority risks are promptly addressed and reported to management.

- iii. **SCALES:** Having a standardized approach for conducting qualitative risk analysis is essential, particularly given the complexities surrounding the perception of risk across different cultures, as previously explained in section 4.2. To facilitate this, frameworks have been developed to guide the project team in performing qualitative risk assessments. These frameworks are based on the risk standard criteria established for conducting qualitative risk analysis at Bosch. However,

recognizing that these original criteria were too complex and time-consuming, they have been simplified to encourage and streamline the qualitative analysis process.

The revised criteria focus on evaluating the severity of impacts from identified threats, as well as assessing the potential effects of positive risks. Additionally, criteria have been established to address the probability of occurrence for each identified risk. This comprehensive set of criteria, which provides a clear guideline for risk assessment, is thoroughly outlined in Appendix II. By adhering to these standardized criteria, the team can ensure a more consistent and efficient risk analysis process, enhancing the overall effectiveness of RM efforts.

The quantitative analysis process requires significant improvement within the project, as identified in section 4.2. This subsection highlights that quantitative analysis is conducted less frequently than qualitative analysis, underscoring the need for enhancement. To address this issue, a more structured and systematic approach is recommended. This approach should involve close collaboration among the PjM, the Core Risk Team, and other relevant stakeholders, supported by a RM expert. The analysis should prioritize, at a minimum, the Top 5 Highest-Rated Risks, ensuring that the most critical areas are adequately addressed with the necessary attention and resources.

However, one of the major challenges in RM practices at Bosch is the difficulty in accessing certain information related to monetary costs. Given the size of the organization, obtaining precise data on the costs associated with specific risks or potential response actions is often a complex and time-consuming process. To address this issue, the development of a user-friendly tool is proposed. Such a tool would streamline the retrieval of cost-related risk analyses across various departments, providing valuable insights that are crucial for informed decision-making. Moreover, it would serve as a motivational factor for project teams by simplifying and accelerating their access to essential data. By enhancing the availability and usability of this information, Bosch can cultivate a more proactive approach to RM, ultimately improving project performance and outcomes.

- iv. ROLES & RESPONSIBILITIES:** In this project, the responsibility for RM is primarily held by the PjM, with additional responsibility assigned to the Sub-Project Managers for their respective domains, as previously outlined in Figure 27.

While the PjM has overall accountability for RM, it is recommended that the responsibility for updating SuperOPL and managing risks should be shared across all teams. This collaborative

approach ensures that each team actively contributes to the RM process, enhancing ownership and accountability.

However, it would be highly beneficial to have a dedicated RM specialist supporting the project, particularly focusing on RM activities. Such a role would alleviate the burden on the project team, ensuring that RM is given the necessary attention despite heavy workloads and time constraints. A specialized risk manager could help maintain the integrity of RM processes, prevent risks from being overlooked, and support the consistent updating of SuperOPL, contributing to a more robust and proactive RM culture within the project.

v. BUDGETING: A key proposal for enhancing the budgeting process is to establish a contingency reserve specifically allocated for unforeseen risks, representing a predetermined percentage of the total budget. This reserve will ensure quick access to funds when unexpected challenges arise, significantly improving the project's financial resilience. To implement this effectively, a comprehensive analysis should be conducted collaboratively by the PjM, Project Sponsor, and other relevant experts. This analysis will review the existing budgeting framework and examine how different financial adjustments could influence the project's overall success, thereby enabling the team to respond swiftly to emerging risks without disrupting the overall budget.

vi. PLANNING: Establishing a meeting schedule and determining the frequency of these meetings in alignment with the PLC activities is essential and will be further discussed in section 5.3. This schedule should be tailored to meet the specific needs of the project's RM requirements. Additionally, developing a standardized approach for these meetings will ensure that all relevant information is consistently captured and documented, facilitating the effective tracking and monitoring of potential risks.

To address more technical or complex risks, extraordinary meetings with the Core Risk Team should be scheduled as necessary. Moreover, domain-specific meetings should be arranged to review risks with each Sub-Project Manager of each domain, ensuring that risks are evaluated in detail within the context of each domain's expertise. This approach will enhance the team's ability to address targeted issues and foster collaboration on risks that span multiple domains.

vii. FORMS & TEMPLATES: In this project, as well as in BG, the Probability and Impact Matrix serves as the primary format for RM. This is particularly advantageous because it is automatically generated by SuperOPL during the qualitative risk analysis process, making it a practical tool for

the team. Utilizing this matrix allows for a clear visualization of risks based on their likelihood and potential impact, streamlining decision-making.

Moreover, as previously mentioned, all identified risks must be documented in the software using a consistent format that adheres to the *"If... Then..."* logic. Although the software encourages this practice, it is frequently overlooked. Implementing this standardized approach is crucial, as it ensures that each risk is uniformly recorded, which in turn facilitates more effective analysis and comparison. By maintaining a consistent format, the team can efficiently aggregate and prioritize risks, significantly enhancing communication and overall effectiveness in the RM process.

viii. MONITORING: To effectively track identified risks, implement risk responses, and evaluate the effectiveness of RM, several methods have been proposed. As has been primarily practiced in the project, each risk measure must be formally closed by the responsible individual upon completion, followed by approval from the PJM. Additionally, it is crucial to assess the effectiveness of the implemented measures utilizing the feedback fields provided by SuperOPL.

Moreover, it is crucial to indicate whether a risk has occurred and, if so, to provide a detailed description of its impact. This practice would significantly contribute to a robust **Lessons Learned** database, serving as a comprehensive documentation hub for the project. This section should encompass thorough descriptions of previous risks, proposed response actions, the processes employed for implementing selected measures, and the rationale behind not pursuing alternative actions or why they may have failed. By consolidating this knowledge, the project team can enhance future RM practices and cultivate a culture of continuous improvement, ultimately leading to better project outcomes.

5.2 Risks Workshop

As projects become increasingly complex and expansive, fostering a robust RM culture within the team is essential. To support this initiative, a specialized workshop is conducted to introduce RM best practices and actively engage all team members. The primary objective of the workshop is to raise awareness of potential risks and ensure consistent application of standardized RM processes throughout the project, fostering a cohesive approach to RM.

The workshop content closely aligns with the RM process outlined in section 2.3, emphasizing key concepts and best practices vital for effective RM across all stages of the PLC. A significant component of the workshop is focused training on the SuperOPL tool, crucial for efficient risk tracking and

management. Some team members were previously unfamiliar with the tool, which led to inefficiencies in the RM process. This training equips participants with the skills and confidence needed to use SuperOPL effectively, thereby streamlining the RM approach.

The workshop begins with a crucial clarification of the distinction between "Risk" and "Problem", terms that are frequently mixed. As depicted in Figure 31, risks refer to potential future events that may affect the project, while problems are existing issues that hinder current progress. This differentiation is fundamental to ensuring a precise and effective approach to RM.

	Problem	Risk
Impact	has occurred	can occur
Measures	corrective	preventive
Mindset	tactic	strategic
Time Frame	short	long

Past

Future

Figure 31: Differences between Risk and Problem (Bosch, 2024d)

Furthermore, the concept of "Risk" can signify a threat with negative impacts on project objectives or an opportunity with positive outcomes. After clarifying these distinctions, it is important to standardize how risks are communicated across the team. As shown in Figure 32, every risk has a cause and leads to an effect. The impact of a risk is determined by its underlying cause, the probability of its occurrence, and the effect it will have on the project.

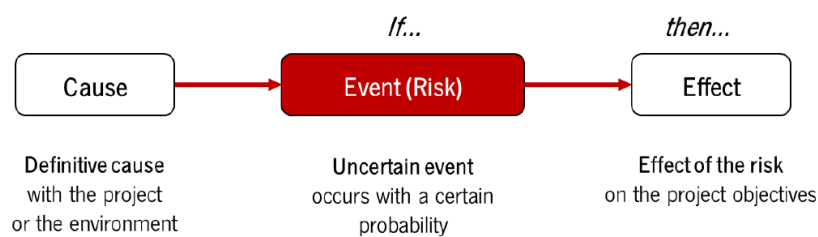


Figure 32: Contextualization of Risks (Bosch, 2024d)

To promote consistency and clarity, the team should adopt the "If... Then..." format when describing risks. This structured approach facilitates standardized communication of both causes and effects. Since SuperOPL encourages this format, reinforcing its use within the team is crucial.

Following this overview, the workshop systematically examines the RM processes, starting with risk identification. This phase emphasizes recognizing potential risks (both positive and negative) that could

impact the project. The project team receives instruction on effectively utilizing SuperOPL to streamline the gathering and documentation of these risks.

Next, the workshop covers risk qualitative analysis, involving multiple team members to enrich discussions about each identified risk. This collaborative approach prevents singular viewpoints and encourages diverse perspectives. The criteria for conducting this analysis, detailed in Appendix II, are thoroughly explained. Additional guidance on documenting the outcomes of the risk analysis within SuperOPL is provided, along with a detailed explanation of how to interpret the Impact-Probability Matrix.

The workshop also addresses risk quantitative analysis, which evaluates the most critical risks identified. This comprehensive approach ensures that the team understands the potential impacts of these risks and effectively prioritizes them, allowing for the development of appropriate response strategies.

In the risk response plan process, the importance of developing effective measures to manage identified risks is emphasized. These measures serve as proactive strategies aimed at minimizing potential negative impacts and optimizing opportunities. A concise guide is provided on how to create these measures within the SuperOPL tool, ensuring all team members can apply them effectively.

The next section focuses on the implementation of measures, encouraging the team to continuously review the Risk List. This ongoing process ensures that team members actively manage their assigned tasks related to risk minimization. By regularly revisiting the Risk List, the team can monitor the status of each identified risk, adjust strategies as necessary, and remain vigilant in addressing emerging threats.

In the risk control section, best practices for evaluating the effectiveness of response measures are introduced. Team members are guided on the importance of providing relevant feedback based on established guidelines whenever a risk is closed. This process includes updating the final status of risk characteristics and responses, as well as documenting outcomes as Lessons Learned for future reference.

The workshop was conducted at the “*Starting Point*” indicated in Figure 26 and should be held at the beginning of each QGC, as these represent critical milestones in the PLC. Since the same workshop was previously held at the start of the PLC for QGC0, the initial concepts were not revisited during this session for QGC2. Instead, the project team systematically reviewed the Risk List, examining each domain individually. They assessed the status of identified risks and engaged in discussions to determine the necessary measures to address these risks and seize potential opportunities. This collaborative approach not only deepened the team's understanding of possible threats but also facilitated the development of actionable strategies for effective RM throughout the PLC.

5.3 Risk Meetings Routine

A new routine has been proposed to enhance the RM process by fostering effective communication and ensuring that risks are consistently monitored and addressed in day-to-day operations. This routine aims to embed RM into the project's ongoing activities rather than limiting it to isolated events or reports.

To support this, a series of targeted meetings is recommended, each with a specific focus and purpose, ensuring that RM topics are addressed regularly. This structured approach facilitates continuous risk assessment and management, encouraging all team members to stay actively engaged in RM efforts. Additionally, this routine seeks to build a strong culture of risk awareness throughout the project. By making RM part of everyday practices, team members are empowered to proactively identify, discuss, and address risks.

The weekly Team Meeting serves as a key opportunity for all members, particularly those in the Core Team, to gather. However, time limitations often impede in-depth discussions on newly identified risks and lessons learned. To mitigate this issue, it is recommended to extend the meeting duration by an additional 30 minutes, as highlighted in yellow in Figure 33.

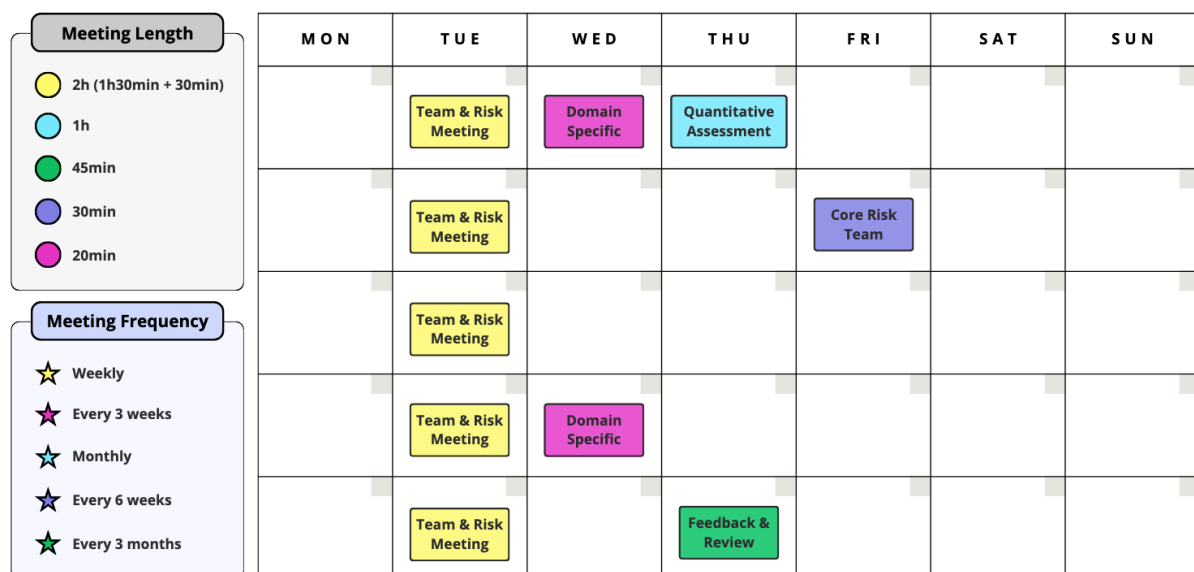


Figure 33: Monthly Overview of RM Meetings

During this extended session, the team will concentrate on risk identification, including the creation of new risks and corresponding measures in SuperOPL. They will also filter these new risks and perform qualitative analyses with relevant stakeholders. This dedicated time allows team members to discuss emerging risks, share valuable lessons, and ensure that critical insights are documented and acted upon promptly.

In addition to the team meeting, dedicated meetings were organized for each specific domain, as represented in Figure 33. These sessions, led by the PJM and involving each specific Sub-Project Manager, filtered the Risk List by domain tags to review existing risks pertinent to each domain. Highlighted in pink, this focused approach ensured that all domain-specific risks were thoroughly addressed and monitored effectively during these sessions.

Furthermore, to conduct effective risk analysis, particularly regarding quantitative assessments, monthly meetings should be scheduled. These meetings, represented in blue, should include the Core Risk Team, the PJM, and other relevant stakeholders, providing a crucial forum for discussing and analyzing the financial implications of the risks tagged as "TOP 5" in SuperOPL.

Every six weeks, a thirty-minute meeting should be held with the Core Risk Team, represented in purple. This meeting will monitor the risks and measures currently in progress, discuss other relevant topics, and review essential aspects of the RM process. Including key stakeholders will facilitate discussions on technical details and ensure comprehensive follow-up on risk-related issues.

Lastly, it is important to schedule a feedback meeting with the Core Risk Team and the Project Team to evaluate the RM process improvements achieved over the past few months. This meeting will assess what is working effectively and identify areas for improvement from the team's perspective, along with evaluating meeting frequency and potential adjustments to the agenda.

Conducting this review will ensure that the RM routine continues to align with the project's needs. It will also provide a platform to discuss the outcomes of risks that have materialized, analyze their impacts, and evaluate the effectiveness of implemented risk measures. This feedback will contribute to the Lessons Learned database, fostering continuous improvement in future RM practices.

By embedding these practices into the team's routine, the project can cultivate a robust RM culture where team members are actively engaged in identifying and addressing risks. The proposed weekly follow-up meetings will facilitate continuous dialogue about risk, enabling team members to share insights that can inform future strategies.

5.4 Quality Gate Customer Tasks Management

Implementing improvements in the management of tasks related to QGCs is essential for ensuring timely completion and enhancing overall project performance. Given that QGs are considered a major RM tool, effectively managing the tasks associated with these gates is critical for identifying and addressing

potential risks early in the PLC. Acknowledging this need, specific measures have been established to improve the management of QGC2 tasks within the project under study.

The primary objective of these enhancements is to ensure that all tasks associated with QGC2 are prepared well in advance. This proactive strategy not only facilitates a smoother workflow but can also significantly impact the effectiveness of the QGCs in the RM process. To achieve this, the questions related to QGC2 from the questionnaire were transformed into actionable tasks, each assigned to a responsible. After confirming individual responsibilities, tasks were created with a due date set three months prior to the QGC2 deadline, as showed in Figure 34.

Type	ID	Creation	Owner	Subject	Category	Source	Responsible	Due date
T		26.09.24	Silva S.	[QGC2] QGC Preparation	OneQ			27.06.25
T		25.09.24	Silva S.	[QGC2] QGC Preparation	OneQ			19.03.25
T		25.09.24	Silva S.	[QGC2] QGC Preparation	OneQ			19.03.25
T		25.09.24	Silva S.	[QGC2] QGC Preparation	OneQ			19.03.25
T		25.09.24	Silva S.	[QGC2] QGC Preparation	OneQ			19.03.25
T		25.09.24	Silva S.	[QGC2] QGC Preparation	OneQ			19.03.25
T		25.09.24	Silva S.	[QGC2] QGC Preparation	OneQ			19.03.25
T		25.09.24	Silva S.	[QGC2] QGC Preparation	OneQ			19.03.25
T		25.09.24	Silva S.	[QGC2] QGC Preparation	OneQ			19.03.25
T		25.09.24	Silva S.	[QGC2] QGC Preparation	OneQ			19.03.25
T		25.09.24	Silva S.	[QGC2] QGC Preparation	OneQ			19.03.25
T		25.09.24	Silva S.	[QGC2] QGC Preparation	OneQ			19.03.25

Figure 34: Overview of QGC2 Tasks Creation (SuperOPL Software, 2024)

This advance preparation fosters accountability by clearly defining responsibilities for each task, enabling the project team to track progress effectively and address any potential delays. Additionally, it provides a buffer period to rectify any issues or requests for corrections that may arise.

This approach was specifically implemented for QGC2 of the project under study, but it should be adopted as a standard practice across all subsequent QGCs and within the BG. By establishing this systematic method for task management, the project team enhances its ability to meet deadlines while reinforcing accountability and strengthening the overall RM framework.

5.5 SuperOPL Improvements

The SuperOPL tool is central to project RM and task management, providing a platform for tracking updates and monitoring team progress. However, continuous use has revealed several areas for

improvement that could enhance its functionality and overall effectiveness. These proposed enhancements aim to streamline the RM process, improve data accuracy, and boost team engagement, ensuring that SuperOPL effectively supports the team's ability to proactively manage risks and tasks throughout the PLC.

- i. **RISK CREATION WITHIN MEETING MINUTES:** Currently, team members must leave the Meeting Minutes tool to access the Risk List when documenting new risks. To enhance efficiency, it is proposed to integrate risk creation directly within the Meeting Minutes tool. This integration would streamline risk registration, eliminate tool switching, and improve real-time capture of risks during discussions, leading to a more effective RM process.
- ii. **ALLOCATING RESPONSIBILITY FOR RISK TAGS:** The current SuperOPL version allows responsibility assignments only for tasks in the Open Points List, leading to missed notifications for risk updates. To improve RM, it is recommended to enable the assignment of one or more responsible individuals to each risk, as risks may have multiple tags representing different domains, as outlined in subsection 3.2.3. This change would ensure timely alerts for designated individuals, fostering accountability and proactive risk monitoring.
- iii. **RISK CLOSURE FRAMEWORK:** In the current system, users only provide the reason for closing a risk, often neglecting to state whether it occurred. To improve this process, it is proposed to introduce a mandatory field requiring users to indicate if the risk happened. If it did, an additional field would prompt a description of its impact. Capturing this information will enhance analysis of past risks, inform future RM strategies, and contribute to a repository of Lessons Learned.

The proposed optimizations for SuperOPL are crucial for enhancing the efficiency and effectiveness of RM. By integrating new functionalities and refining existing processes, the tool will provide better support for teams in their efforts to identify, assess, and manage risks, ultimately contributing to more successful project outcomes. These improvements will foster a more proactive and organized approach to RM, ensuring that teams are equipped to navigate challenges and seize opportunities throughout the PLC.

6. FINAL CONSIDERATIONS

The primary objective of this case study was to investigate the contribution of RM within the context of an NPD project. By examining QGs as indicators of project quality, the research aimed to explore the role of RM in identifying risks and opportunities for improvement across various phases of NPD projects. The study aimed to answer the critical research question:

“In the context of New Product Development, do Risk Management practices contribute to the quality of the project?”

The investigation identified key challenges and opportunities within the RM processes of the analyzed project. Based on these findings, actionable recommendations were proposed to improve the current RM practices.

This chapter is organized into two main sections that comprehensively address the investigation's findings and implications. Section 6.1 presents the conclusions drawn from these findings, along with a discussion of the limitations of the case study. Building on this, section 6.2 offers recommendations for future work based on the insights and limitations outlined earlier. These recommendations aim to identify potential directions for further research and suggest actions that can enhance the current case study's findings.

6.1 Research Contributions and Limitations

This study has conclusively shown that effective RM practices significantly contribute to enhancing the quality of projects, thereby providing a meaningful response to the research question. In the context of the NPD project under investigation, several inefficiencies in RM practices were identified, reflecting challenges commonly observed in other projects

Specifically, several weaknesses were identified in the RM planning phase, particularly regarding the essential components of the RMP. In response to these deficiencies, a comprehensive set of targeted improvements was proposed, emphasizing the enhancement of RM practices with the ultimate goal of significantly improving overall project quality.

Despite the well-founded proposals, the study encountered significant challenges, primarily due to time constraints and unforeseen circumstances, which limited the implementation and analysis of the proposed improvements within the project context. Nevertheless, several measures were successfully executed during the research, particularly those that required minimal restructuring. For example, risk

meetings were organized for specific domains, and tasks arising from the QGC2 project questionnaire were promptly addressed. However, the actual impact of these changes remains unexamined.

A critical limitation that impacted the implementation of certain improvements was the timing of the study, which coincided with the summer season, resulting in fluctuating attendance among project team members. This inconsistency highlighted that restructuring workflows would not produce meaningful results without the consistent participation of all team members.

Another significant limitation encountered was rooted in the organizational dimension, particularly in obtaining necessary information and in communication with colleagues, which was rarely immediate. Often, the team's availability did not align, and accessing specific data or information required a sequence of contacts with individuals dispersed throughout the organization on a global scale.

Lastly, it is important to highlight that RM is not yet implemented at the expected level within the organization. There is a clear immaturity in the company regarding the processes related to the subject under study, which are predominantly conducted in a highly intuitive, non-standardized, and informal manner. This situation is often justified by tight deadlines and a general lack of available time.

6.2 Suggestions for Future Work

Considering the findings of this research, it is evident that establishing a robust risk culture is critical for advancing an organization's RM processes. This mindset must be deeply integrated into the company's culture and requires strong leadership support. To foster such a culture, it is essential for leaders to actively promote RM initiatives and emphasize the value of RM within the organization. Furthermore, it is important that all employees comprehend its significance and how it aligns with the broader goals and mission of the organization.

Looking forward, Bosch Braga should clearly define its priorities, aligning them with top management's strategic direction and the long-term vision for the business group's goals and mission. The research presented in this study addresses a significant and relevant topic within PM, offering valuable insights and setting the stage for future investigations. These subsequent studies may build upon the contributions made, providing further opportunities to refine and strengthen the organization's PM practices.

The findings and insights derived from this study provide a robust foundation for the implementation of both standardized and customized RM practices, not only within NPD projects but across Bosch's global organization. Future research could expand on these findings by exploring the influence of additional variables, such as project structure and duration, on project quality outcomes. This broader perspective

will help organizations gain a more comprehensive understanding of how various factors interact, ultimately supporting the optimization of RM practices and contributing to more successful project results.

In summary, the proposals and achievements outlined in this thesis offer a clear roadmap for further enhancing RM practices within the automotive industry. Moving forward, it is recommended that efforts be directed towards fostering a strong RM culture, emphasizing the benefits that this process brings to the organization and its employees. By building on the findings of this research, the organization can continue to strengthen its RM framework, ultimately driving success in future projects and ensuring more consistent and effective project outcomes.

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APPENDIX I DETAILED DATABASE FOR ANALYSIS³

Table 20: Comprehensive Project Data Overview

ID	Project Category	OVERALL QGC RATING						RM RATING					
		QGC0	QGC1	QGC2	QGC3	QGC4	QGC5	QGC0	QGC1	QGC2	QGC3	QGC4	QGC5
1	B	Y	Y	R	Y	Y	Y	Y	Y	R	Y	Y	Y
2	C	Y	Y	Y	Y	Y	Y	G	Y	Y	Y	Y	Y
3	B	Y	Y	Y	R	Y	Y	G	Y	Y	R	Y	Y
4	A	Y	R	R	Y	Y	G	Y	Y	Y	Y	G	G
5	B	G	Y	Y	Y	Y	Y	G	Y	Y	Y	G	Y
6	C	G	G	Y	R	Y	Y	G	G	Y	R	Y	Y
7	B	Y	G	Y	Y	G	G	Y	G	Y	Y	G	G
8	C	G	Y	Y	Y	Y	Y	G	Y	Y	Y	Y	Y
9	B	Y	Y	G	Y	R	Y	Y	Y	G	Y	Y	Y
10	B	G	Y	Y	Y	Y	Y	G	G	Y	Y	Y	Y
11	C	Y	Y	Y	G	Y	G	G	Y	G	G	Y	G
12	C	Y	Y	N/A	N/A	Y	Y	G	Y	N/A	N/A	Y	Y
13	A	Y	Y	R	R	R	Y	Y	Y	R	R	R	Y
14	B	Y	G	Y	Y	Y	Y	Y	G	Y	Y	Y	Y
15	A	Y	Y	R	Y	Y	Y	Y	Y	R	Y	Y	Y

³ For projects 12, the assessments for QGC2 and QGC3 were skipped.

APPENDIX II CRITERIA FOR QUALITATIVE RISK ASSESSMENT

Table 21: Criteria for Assessing the Severity of Negative Risk Impacts

THREATS	DOMAIN		
SEVERTY OF IMPACT	Spefication/Quality	Cost	Time
Very High	Significant departure from the specification, considered unacceptable by the customer. This flaw could pose serious safety risks and/or contravene legal regulations.	> 20-40% increase in costs	Postponement of important delivery dates (e.g. testing, release samples). Postponement of other milestones. May cause SOP to be postponed.
High	Noticeable divergence from the specification, seemed unacceptable by stakeholders. The device's operational capacity is significantly compromised.	20-40% increase in costs	Postponement of important delivery dates (e.g. testing, release samples) and/or QGCs. Negative effects on SOP currently not expected.
Medium	Significant divergence from the specification, yet likely tolerable for all stakeholders.	10-20% increase in costs	Postponement of few important delivery dates (e.g. samples) and/or milestones. Acceptable for the customer.
Low	Minor variation from the specification. The flaw is considered to have minimal significance.	< 10% increase in costs	Internal postponement of date only. No significant changes in the overall project schedule.
Very Low	Minor variation from the specification. The flaw is not expected to have any noticeable impact on the device's performance.	no significant increase in costs	Small internal postponement of date only. No significant changes in the overall project schedule.

Table 22: Criteria for Assessing the Severity of Positive Risk Impacts

OPPORTUNITIES	DOMAIN		
SEVERTY OF IMPACT	Spefication/Quality	Cost	Time
Very High	Significant enhancement of product quality, exceeding customer expectations. Provides substantial value to processes and products.	> 40% decrease in costs	Results in considerable time savings, accelerating project milestones. Improves important delivery dates for customers.
High	Clear improvement in product characteristics that greatly benefits stakeholders. Transformational effect on project success.	20-40% decrease in costs	Notable time savings in the project schedule, enhancing customer delivery dates and key internal milestones.
Medium	Moderate alignment with quality standards, resulting in noticeable improvements. Increases stakeholder satisfaction.	10-20% decrease in costs	Minor time savings on internal milestones, with no major improvements to the overall project schedule.
Low	Minor alignment with quality specifications, yielding slight improvements. No significant benefits to stakeholders.	< 10% decrease in costs	Limited time savings that do not materially affect the overall project timeline.
Very Low	Negligible enhancement to quality specifications, offering minimal improvements to the product. No meaningful benefits to stakeholders.	No significant decrease in costs	No noticeable advantage on the overall project schedule. Minor time savings within departments only.

Table 23: Assessment of the Probability of Risk Occurrence

PROBABILITY	CRITERIA	LIKELIHOOD
Very High	> 75%	Almost certainly will occur
High	51% - 75%	More likely to occur than not
Medium	26%-50%	Fairly likely to occur
Low	6% - 25%	Unlikely to occur
Very Low	< 5%	Extremely unlikely or virtually impossible

ANNEX A BOSCH GROUP

In 1886, at the age of 25, Robert Bosch founded his first precision mechanical and electrical workshop in Stuttgart, southern Germany. The company's logo originates from the magneto, Robert Bosch's first invention, a low-voltage magneto used in automobile ignition systems. This logo, illustrated in Figure 35, has remained similar to this day and is globally recognized as the company's image.



Figure 35: Bosch Group Logo (Bosch, 2023a)

World leader in technology supply, the BG has built its history on a strategy aimed at delivering technological services for a more connected life, without neglecting global sustainability. The company invests significantly in Research & Development (R&D) talent, including Portuguese researchers, to maintain its cutting-edge position in innovation (Bosch, 2020).

As represented in Figure 36, the BG operations are divided into four business areas: i) Mobility Solutions (BBM); ii) Industrial Technology (BBI); iii) Consumer Goods (BBG); and iv) Energy and Building Technology (BBE). The BBM area accounts for the largest percentage of the BG sales, reaching 60% of the organization's revenue in 2022 (Bosch, 2022b).

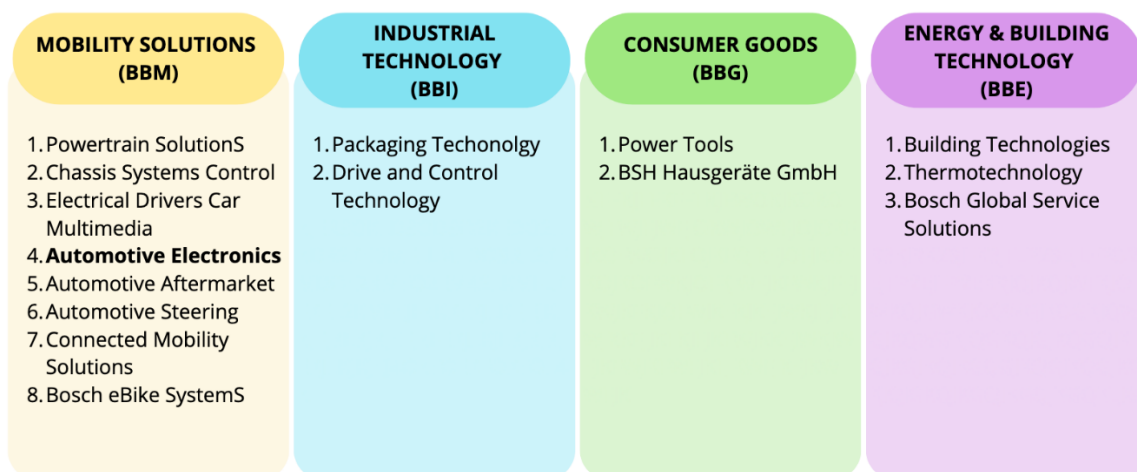


Figure 36: Sectors of Activity of the BG (Adapted from Bosch (2023a))

Currently, nearing 140 years of existence, the BG presents itself as a leading provider of technology and services, being present in 60 countries in 2023 with 468 subsidiaries and regional companies. It employs approximately 429,400 employees worldwide, generating a total of 91.6 billion euros in sales that year (Bosch, 2023b).

The BG is globally recognized for its excellence, reliability, and focus on customer satisfaction, positioning it as a trusted brand worldwide. With a strong presence, the company offers high-quality solutions that positively impact various industries and improve people's lives. Its continuous commitment to technological advancement, combined with a dedication to sustainable practices, ensures that Bosch remains at the forefront of innovation. In this way, the company transforms the way people live, work, and move in an increasingly globalized and interconnected world through technology and the internet (Bosch, 2023b).

Present in Portugal since 1911, Bosch is one of the most recognized companies in the country. Currently, there are four different Bosch locations in Portugal, with three being industrial units: i) Bosch Car Multimedia Portugal in Braga; ii) Bosch Thermotechnology in Aveiro; and iii) Bosch Security Systems in Ovar. As shown in Figure 37, the group currently employs more than 6,600 workers, making the company one of the largest industrial employers in Portugal, and it generated 2 billion euros in sales in 2022 (Bosch, 2022a).

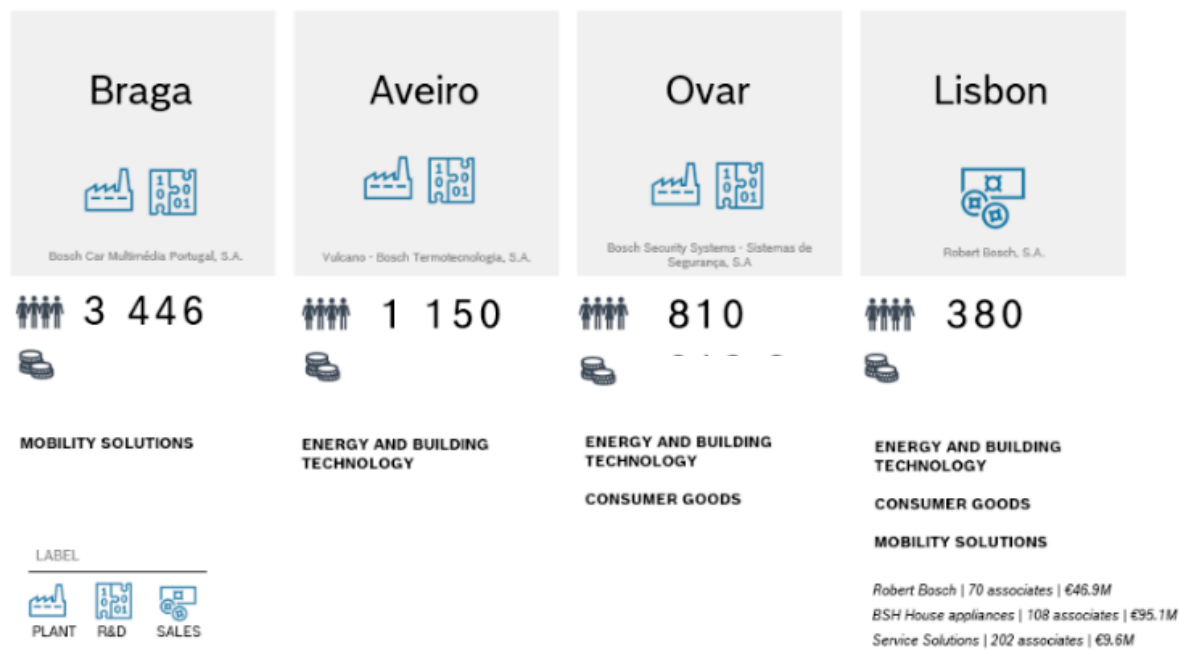


Figure 37: Locations and Basic Information of Bosch Portugal (Bosch, 2022a)

As can be seen from the data in the figure above, Bosch Car Multimedia Portugal, S.A., is the largest company and employer of Bosch in Portugal, with a particular focus on the BBM sector (Bosch, 2022a).

The Bosch unit in Braga has a rich history that dates to 1990, when the Blaupunkt factory was inaugurated, specializing in the production of car radios. From the beginning, it stood out in the national market. A significant milestone occurred in 2009, when, in response to changes in the automotive

industry, the Blaupunkt brand and the car radio aftermarket business were sold. This event catalyzed a restructuring process that culminated in the creation of Bosch Car Multimedia Portugal, S.A (Bosch, 2022a).

Over the years, Bosch Braga has established itself as a benchmark in terms of know-how, developing and producing increasingly complex electronic products with high quality and flexibility (Bosch, 2020). Currently, Braga Plant is the main unit of the Automotive Electronics (AE) division within the BBM sector, being the largest Bosch location in Portugal and one of the largest globally. In 2022, it employed 6,500 people and generated over 2 billion euros in revenue, representing 60% of the revenue from all Bosch units in the country (Bosch, 2022b).

In organizational terms, the company is divided into two functional areas: the Commercial Area and the Technical Area. Each of these areas is subdivided into the departments presented in Figure 38.

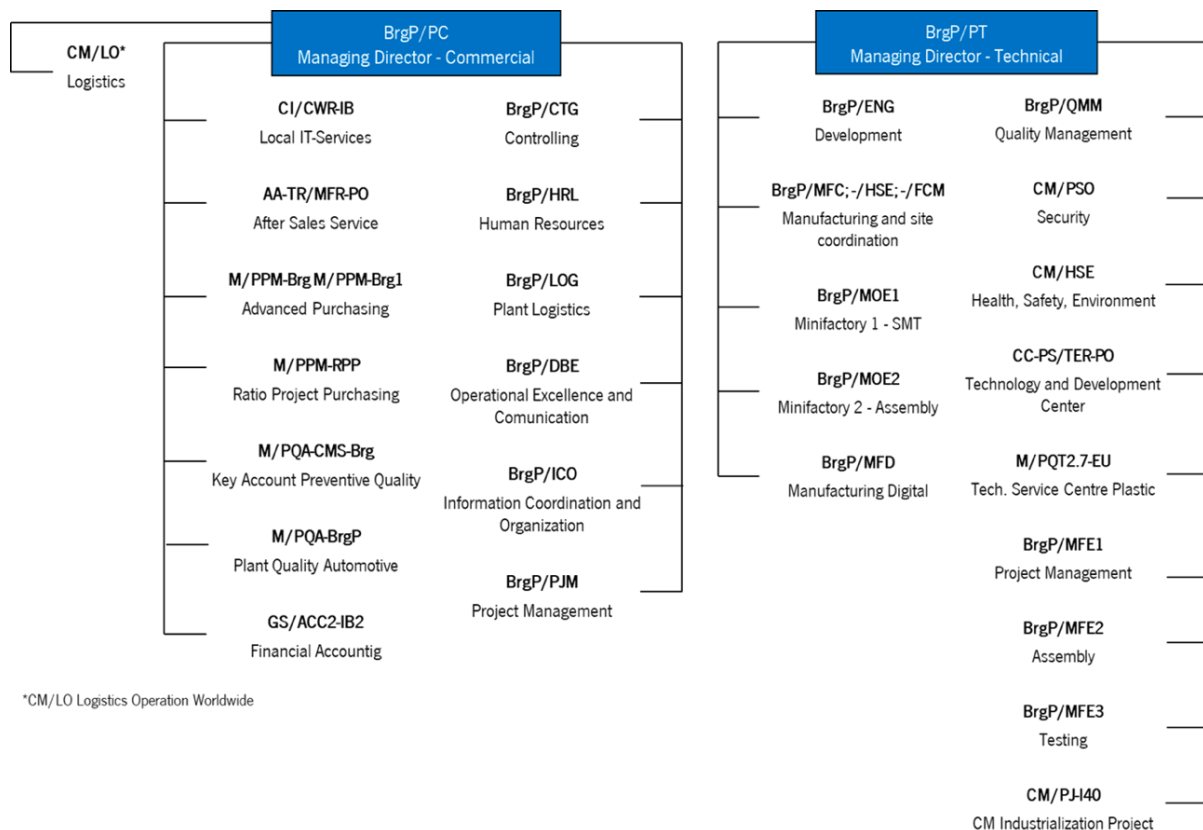


Figure 38: Organizational Chart of Bosch Braga (Bosch, 2024c)

In the Commercial Area, you can find departments that handle activities such as purchasing, logistics, accounting, human resources, and IT support. On the other hand, in the Technical Area, there are departments involved in activities such as production, engineering, quality, health, and safety, among others.

ANNEX B CRITERIA EVALUATION FOR PROJECT CATEGORIZATION AT BOSCH⁴

Table 24: Criteria Evaluation Matrix for Project Categorization (Bosch, 2024b)

CRITERIA	1 Point	2 Points	3 Points	4 Points	5 Points
ECONOMIC IMPACT	≤ 200 TEUR	> 200 TEUR ≤ 1 Mio EUR	> 1Mio EUR ≤ 3 Mio EUR	> 3 Mio EUR ≤ 10 Mio EUR	> 10 Mio EUR
INNOVATION	none, modification	little	new within existing framework	new in new framework	new category / new technology / new division
SUBJECT MATTER EXPERTISE	one field of expertise	2-3 fields of expertise	4-5 fields of expertise	6-8 fields of expertise	> 10 fields of expertise
PROJECT STRUCTURE	without sub-projects, Team size ≤ 3, can be directly managed by PjM (without Sub-Project Managers)	without sub-projects, Team size ≤ 5, can be directly managed by PjM (without Sub-Project Managers)	with up to 3 sub-projects, Team size ≤ 10, can be directly managed by PjM (without Sub-Project Managers)	with up to 5 sub-projects, Team size ≤ 15, Sub-Project Managers or similar management function necessary	with more than 5 sub-projects, Team size > 15, Sub-Project Managers or similar management function necessary
INTERCULTURAL SET-UP	one culture, one location, national	one culture, > 1 location, national	two cultures, > 2 locations, international	> 2 cultures, > 2 locations, international, 1 region	> 2 cultures, > 3 locations, international, > 1 region
RISK EVALUATION	minor risk	low risk	medium risk	major risks	high risk

⁴ Criteria **Economic Impact** and **Risk Evaluation** are double-weighted (x2).

ANNEX C PROJECT LIFECYCLE AND NEW PRODUCT DEVELOPMENT FRAMEWORK AT BOSCH

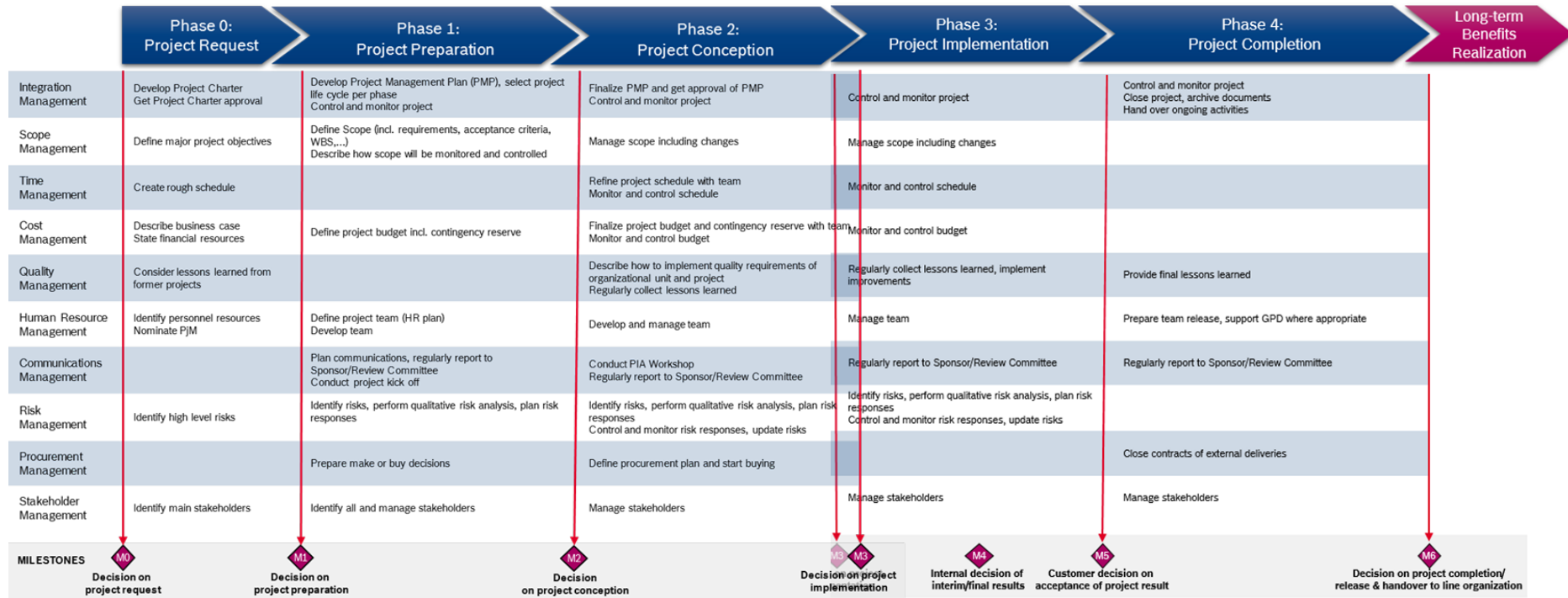


Figure 39: Bosch PLC Model and Detailed Subprocesses (Bosch, 2024a)

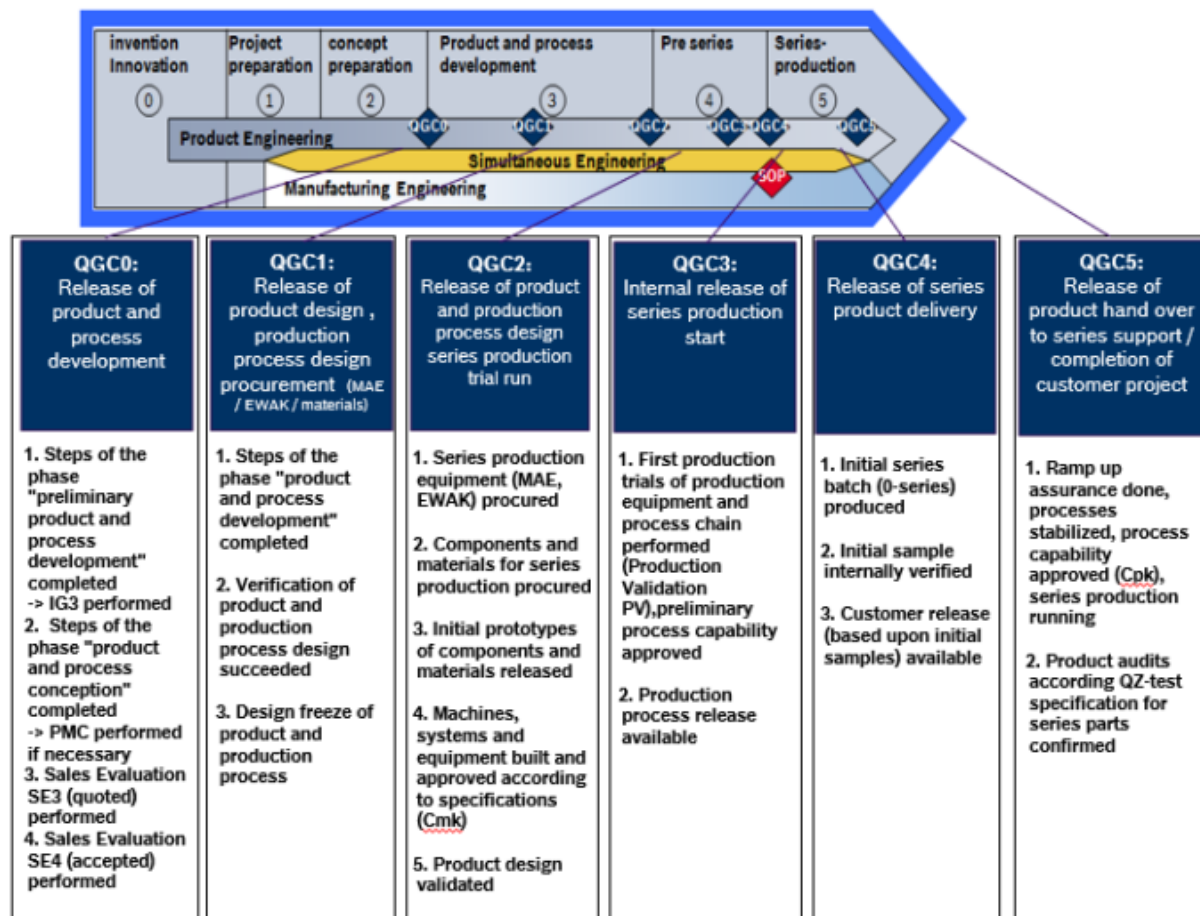


Figure 41: Detailed Activities of each Quality Gate Customer (Bosch, 2024a)

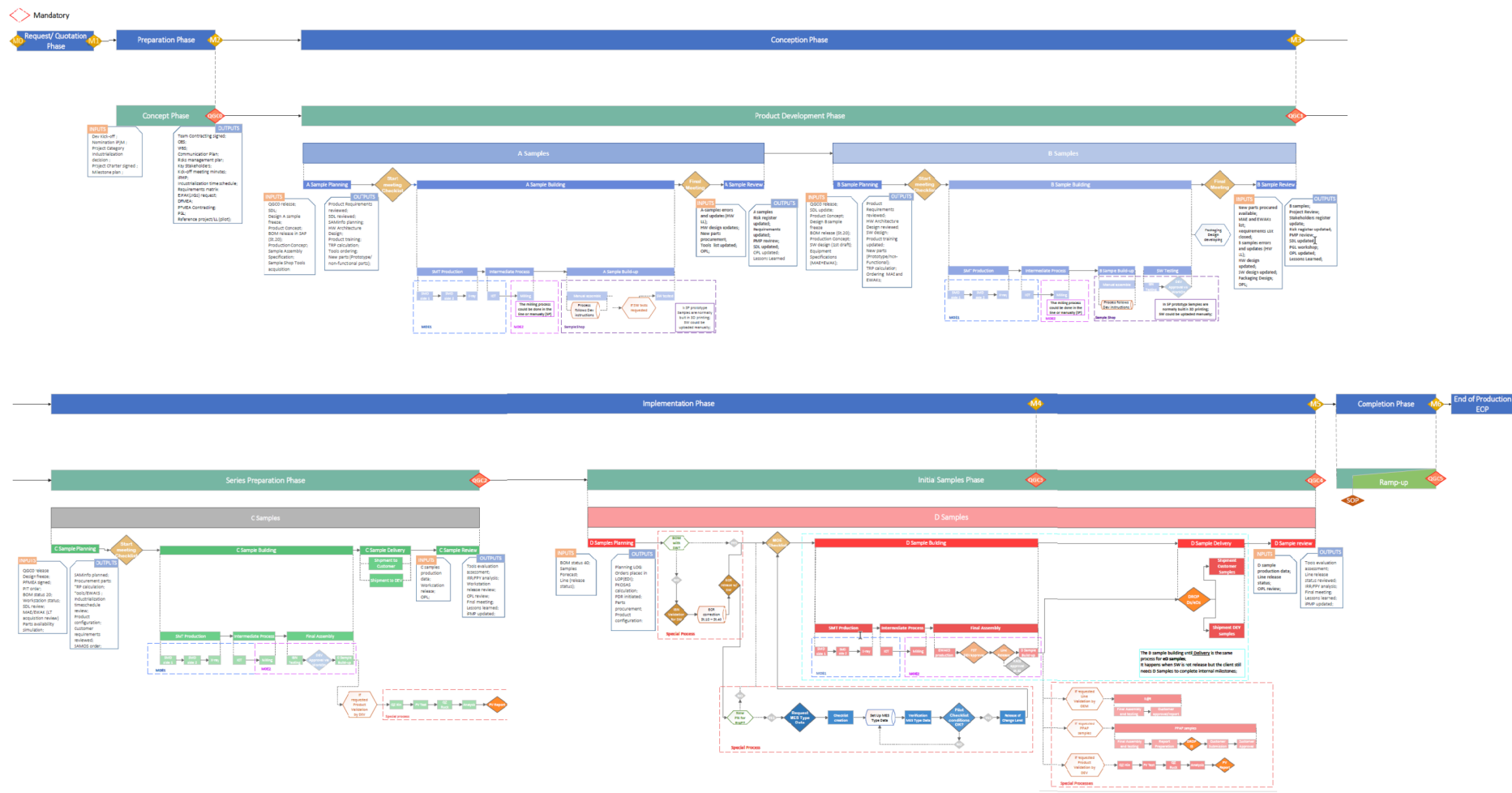


Figure 42: Standard Flowchart for NPD projects (Bosch, 2024a)

ANNEX D METHODOLOGY FOR ASSESSING MEASUREMENT CRITERIA IN QG AT BOSCH

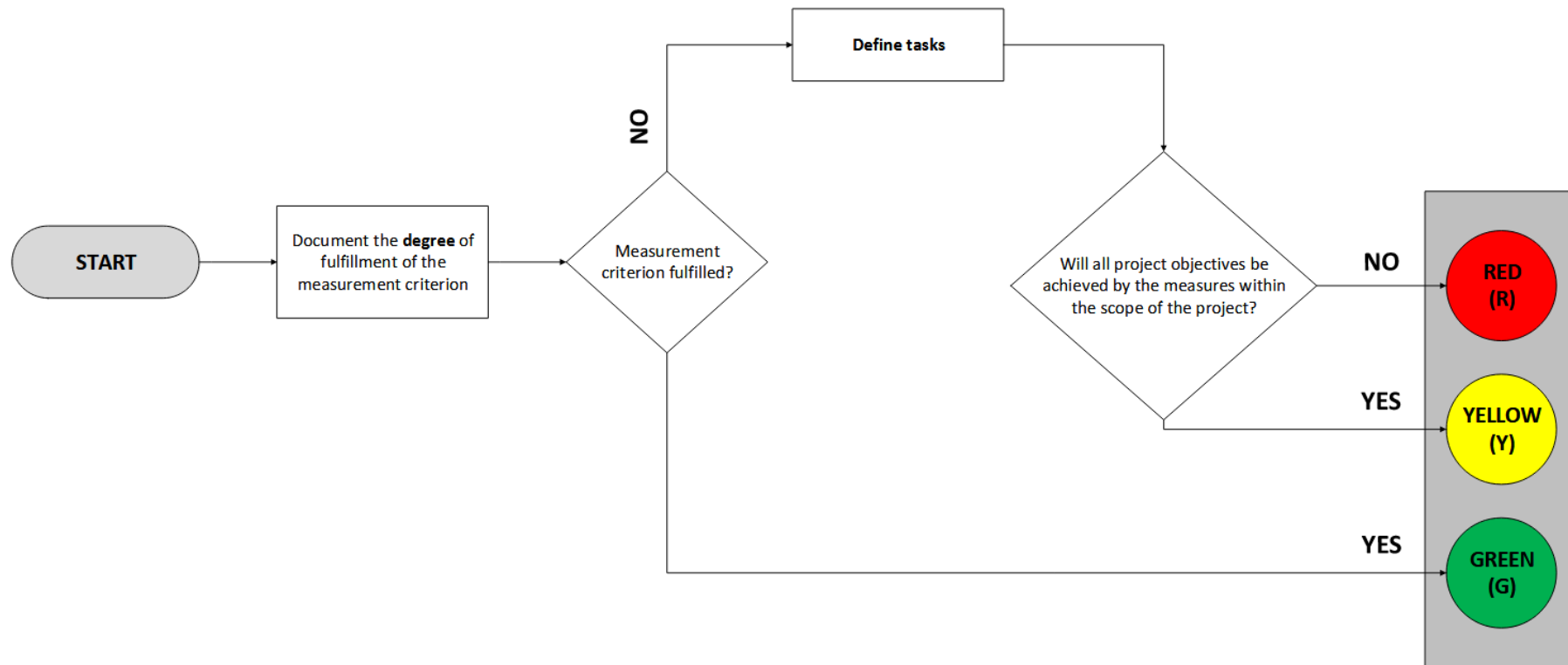


Figure 43: Flowchart for the Assessment of Measurement Criteria in QG (Bosch, 2024b)

ANNEX E SuperOPL SOFTWARE

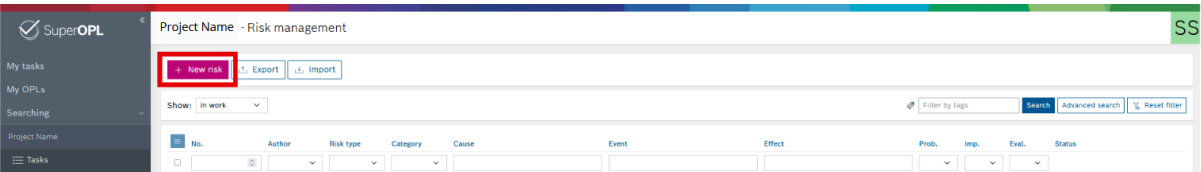


Figure 44: SuperOPL RM Tool - How to Create a New Risk (SuperOPL Software, 2024)

New risk

Information about risk

Type: *

Negative

Category: *

Select

Risk Event: *

(IF) Short description for reporting

Risk Effect(s): *

(THEN)

Tags:

Are other projects or products affected?:

No

Risk Cause:

Risk Indicator:

A risk indicator is a measurable value to monitor and identify the risk before it occurs.

Risk Threshold:

What is the intervention threshold for the indicator

Risk Event Date (Expected):

☒ Show risk in reporting sheet

Note:

Figure 45: SuperOPL RM Tool - Example of New Risk Creation (SuperOPL Software, 2024)

Risk analysis - Qualitative risk evaluation

MM-620.16-901 GP Risk Criteria Catalogue⁶⁵

Probability (current):

(not set) ▾

Probability after measure:

(not set) ▾

Probability note:

Document here "EVENT" as applied from Probability Sheet of MM-620.16-901 GP Risk Criteria Catalogue

Impact (current):

(not set) ▾

Impact after measure:

(not set) ▾

Impact note:

Document here "Risk Aspect(s)" as applied from Impact Sheet of MM-620.16-901 GP Risk Criteria Catalogue

Figure 46: SuperOPL RM Tool - Example of Qualitative Risk Evaluation (SuperOPL Software, 2024)

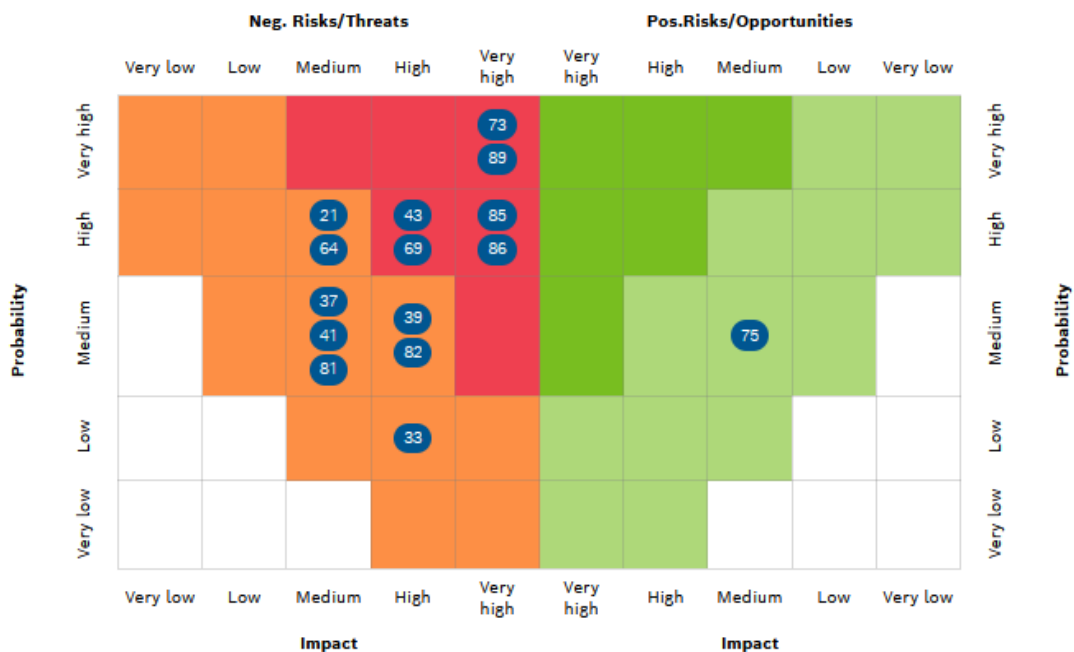


Figure 47: SuperOPL RM Tool - Probability and Impact Matrix (SuperOPL Software, 2024)

Risk analysis - Quantitative risk evaluation

☒ Calculate expected monetary value automatically

Monetary Value before measure:

e.g. 123456 EUR

Monetary Value after measure:

e.g. 123456 EUR

Expected Monetary Value before measure:

e.g. 123456 EUR

Expected Monetary Value after measure:

e.g. 123456 EUR

EBIT effect category:

Select ▾

Sum of costs of measures:

e.g. 123456 EUR

Figure 48: SuperOPL RM Tool - Example of Quantitative Risk Evaluation (SuperOPL Software, 2024)

Response strategy: *	▼ ①
Entry type: *	M - Measure▼
Owner:	Silva Samuel (XC-CP/EPM-Brg) ▼
Start date: *	10.10.24 📅
Priority:	▼
Subject: *	
Description:	
Source:	
Category:	
Tags:	
Meeting:	Select▼
Information to:	👥
Responsible: *	👥
External responsible:	
Due date:	24.10.24 📅
	☐ Confidential ①
Cost of measure:	Whole number, e.g. 123456 EUR

Figure 49: SuperOPL RM – Example of New Measure Creation for a Risk (SuperOPL Software, 2024)

Mestrado em Engenharia e Gestão da Qualidade

**AUTORIZAÇÃO DE UTILIZAÇÃO DE IMAGEM
(DISSERTAÇÃO EM EMPRESA)**

Na qualidade de representante da empresa (especificar), declaro, para os devidos efeitos legais, que autorizo a utilização das fotografias e imagens da empresa (especificar) captadas durante a dissertação em empresa de Samuel Fernandes Silva do curso de Mestrado em Engenharia e Gestão da Qualidade.

Mais declaro, que a autorização de uso das referidas imagens é restrita à sua integração na dissertação do referido estudante, renunciando desde já a quaisquer direitos ou compensação que desta utilização possa eventualmente resultar.

Por ser verdade, e por nada haver a obstar, esta declaração vai ser assinada por mim,

Local e data: Braga, 31 de outubro de 2024

Assinatura: Gerson Nogueira

BI/CC nº: 14849149